



Plastics and Rubber Sri Lanka

The Journal of the Plastics and Rubber Institute of Sri Lanka

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Message from the President

“A Tomorrow Full of Creativity” is the most appropriate expression of our direction this year. The Polymer Industry needs continual development and upgrading of its technological and manufacturing capabilities to be globally competitive.

We are proud to be the management arm of the Finite Element Analysis & Simulation Centre, which is a Public-Private Partnership between the Rubber Research Board (RRB) & the Plastics and Rubber Institute of Sri Lanka (PRISL), supported by the Sri Lanka Association of Manufacturers and Exporters of Rubber Products (SLAMERP). The main role of this innovative technology centre is to enhance the technical and technological capabilities of the Rubber & Plastics industry sectors, to design, model and simulate creative and innovative polymer based products, to support creative minds to re-engineer the current products, also to develop new product concepts.

We offer concessions to Industrialists in the polymer sector, to visit international trade fairs, seminars and

technical training programmes, to expose them to creative ideas and to be abreast of the developing technologies and state of the art machinery.

I take this opportunity to thank the Chairman and the members of the Seminars, Publications & Image Building committee for publishing this Annual Journal which is of very high standard, and The Chairman and the members of the Social Committee for organizing this magnificent Convocation Ceremony. Last but not least I congratulate all the award recipients this evening.

Kalyana Dhirasekera
President
Plastics and Rubber Institute of Sri Lanka



Message from the Hon. Secretary, PRISL

It is with great pleasure that I extend my congratulations on the launch of the 23rd edition of the Annual Journal of our prestigious institute. As the Plasatic and Rubber Institute of Sri Lanka (PRISL), we have continued to collaborate with various industry players, both locally and internationally, to stay updated with the latest advancements in the field. Our membership has also grown steadily, and we have welcomed new members who share our passion for excellence and vision for the betterment of the industry.

I would like to highlight the growth of PRISL in the realm of industry-specific, customized education sector. Over the years, we have continued to expand our educational programs to cater to the growing demand for skilled professionals in the industry. Our institute offers a range of training programs, courses and workshops that provide students with a comprehensive understanding of the latest developments in the field of plastics and rubber technology.

It is with utmost pride we declare that our educational programs have been well-received by students and industry professionals alike. We have continued to receive positive feedback from our students, who

have gone on to make significant contributions to the industry. Our institute's commitment to education is reflected in our mission to develop a skilled workforce that can meet the needs of the industry.

I would like to take this opportunity to show my appreciation to the subcommittee members and administrative staff for their tremendous effort in ensuring the success of this year's Journal. Their commitment and hard work have made this publication possible, and we are grateful for their contribution to the institute's growth and progress.

With great hopes and high ambitions, I invite all stakeholders of the industry to continue to work together and advance the industry to achieve our shared goals.

Prabath Jayasinghe
Honorary Secretary
Plastics and Rubber Institute of Sri Lanka



Note from the Editor’s Desk

The year 2022 had been a year with unprecedented challenges for Sri Lanka’s plastic and rubber sectors. On a global scale, the prolonged, sustained adverse impact of the COVID-19 pandemic was still battering the industries. Disruptions in supply chains and shifting consumer spending patterns in top export markets were creating new hurdles that were never present before.

To add insult to injury, the devastating effects of the economic crisis that brought Sri Lanka to its knees, crippled many of the companies, specifically the SME sector of the industry. Skyrocketing raw material costs, higher electricity tariffs and low consumer demand due to shrinking disposable income compelled many companies to significantly downsize their business operations and aim to survive in this turbulent economic period.

Nevertheless, the creativity, ingenuity and resilience demonstrated by our workforce in the industry, who worked tirelessly to turn the circumstances around to grow and thrive their businesses were remarkable. Our companies launched new products that are trending and in demand by their valued clients, while some went towards modernizing machinery and technology to achieve greater economies of scale and higher product quality. Sri Lankans in the industry have shown that they are truly capable of astonishing feats at the times of despair.

It is on this positive outlook that we have created the 2023 Annual Journal of the Plastic and Rubber Institute of Sri Lanka, which has complemented the

industry with up-to-date technical and managerial courses, from certificate courses to higher diploma qualifications. The Finite Element Analysis & Simulation (FEAS) Centre has been offering our companies with cutting edge product research and testing facilities. On top of that, PRISL took great pride in holding several timely and informative seminars and events that were well received by both stakeholders within the industry and a wider audience.

We are confident that PRISL will be able to continue this trailblazing trend and continue to support the industry to the fullest extent, enabling our companies to reach dizzying heights of success.

Last but certainly not least, I take this moment to extend my heartfelt appreciation to the great team in the Editorial, Seminar, Workshop and Image Building Sub-committee for availing an unparalleled assistance in compiling this Annual Journal to its present state. The PRISL Administration Team also played a pivotal role in making this effort a vibrant success.

I wish them the best of success!

Parakrama B. Jayatissa
Editor



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Sustainable NR Production and the Middle Income Trap

Pong Kai See, FPRI, FPRIM, BSc (Polymer Science), MSc (Tech-Econs), Plastics & Rubber Institute Malaysia.

The original industrial revolution (ca.1750) plus colonization enabled developed countries (G7/8) to become rich at the expense of poor countries and these countries were able to build up big difference in gross domestic product (GDP), per capita income and standard of living. The rate of growth of GDP was moderate by modern standards, perhaps 1.5% to 2.0% per year, but over a period of more than 200 years this amounts to lots of growth.

Adoption by certain developing countries (G20) of methodology of the developed countries, especially structuring away from subsistence agriculture base to industrial export base and joining the global or open economy led to rapid growth that enabled these countries to catch up with the G7. 13 countries (Oman, Brazil, Botswana, China, Japan, Malaysia, S. Korea, Indonesia, Malta, Taiwan, Singapore, Hong Kong, Thailand) achieved greater than 7% growth over 25 years, from 1960s to 2005. In recent years the list has grown (Vietnam, India, Turkey, Bangladesh, S. Africa, etc).

China grew since opening up by Deng Xiaoping in 1978 at a historical pace averaging 9.5% for more than 35 years; and is now the second largest economy in the world, though still poor in terms of GDP per capita. India is according to some sources is 14 years behind. The economic structure of these economies, including the way they deal with each other and the G7 countries, what they sell and what they buy, will change as these new developing countries catch-up and becoming developed countries in another 20 years or so.

Not all the fast developing countries will achieve developed countries status. Many countries stagnate around USD 6,000-10,000 income per capita and are not able to restructure away from labour intensive exports. Of the 13 countries above only 5 (Japan, Hong Kong, Singapore, Taiwan, S. Korea) made it to become developed countries, i.e., per capita income in excess of USD 25,000. This phenomenon is described as “middle income trap” by economists. A study by IMF indicates that perhaps only 1 in 5 middle income countries will make the breakthrough. Malaysia has been stuck in the “middle income trap” since around 2005.

RUBBER SUPPLY

The reason I bring up the subject of fastgrowing countries is because this has relevance when we discuss prospects and development of the world rubber economy. This involves the supply side of natural and synthetic rubber as well as the demand side. On the supply side or upstream sector, for natural rubber producers, as the GDP per capita increases, they become less competitive. A good example is Malaysia (see box) and perhaps China. They also become major synthetic rubber producers (Japan, S. Korea, Taiwan, Singapore, China). On the demand side or downstream sector, they move away from labour intensive or low value-added products to more technologically demanding ones. The rate of growth of new rubber use also slows down. In the 1960s the top 10 rubber using countries (natural and synthetic rubber) were almost all from developed countries. In 2020 the top 10 (China, USA, India, Germany, Japan, Thailand, S. Korea, Malaysia, Indonesia, Brazil) include 7 Asian countries. Thailand, Malaysia and Indonesia became major users of SR since they started SR production. Growth is negative or static in USA, Germany, Japan and S. Korea, the “developed” countries. Vietnam is now the fastest grower.

Adam Smith, “The Father of Economics” writing in “The Wealth of Nations” in 1776, suggested the reason why nations trade was because one country could produce certain goods cheaper than others while another nation produced a different good more economically. It followed that in international trade there exists a ranking of nations. For example, in oil production, the cheapest producer is the one where oil is easiest accessible (Saudi Arabia) while the most expensive oil come from difficult to extract areas (deep sea). We see a similar story in rubber. This is called “comparative country advantage”.

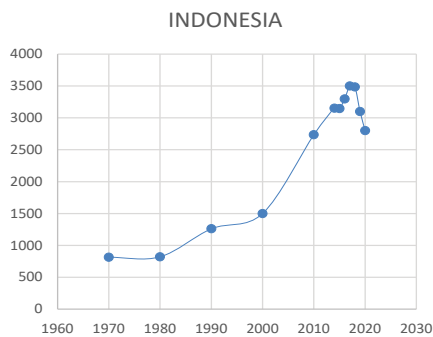
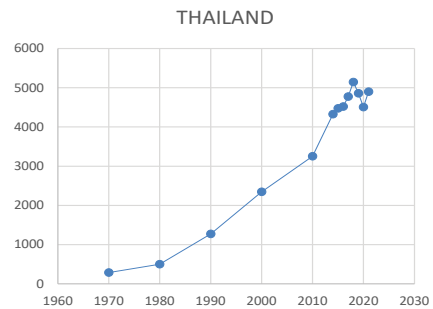
Natural rubber has been around for a long time. Columbus, in his second voyage to the West Indies, observed natives playing a game with a type of rubber ball. The material did not attract attention in the West till Joseph Priestly, the discoverer of oxygen, found it could rub off pencil marks, and Charles Goodyear in 1839 invented vulcanization, a process that made the material useful in both hot and cold conditions. Demand

for rubber quickly grew with invention of telegraph and electricity on the one hand, and the motor car on the other. Rubber was needed to insulate the telegraph and electric wires and to make tyres for motor transport.

Rubber came from wild plants in Brazil, Central America and the Congo. At its peak, rubber was worth its weight in silver and much atrocities were committed by so-called “rubber barons”, who became very rich, on the native population to ensure the rubber reached the factories in Europe and America.

In 1876 Henry Wickham, a British adventurer, smuggled some 70,000 rubber seeds out of the Amazon basin. These were germinated into seedlings in Kew Gardens, London. A few seedlings reached Malaya and Sri Lanka (Ceylon) and these became the original stock of the millions of trees planted in rubber plantations in the Far East. Wild rubber could not compete: with plantation rubber which was thousand times better in efficiency and productivity. By 1920 the rubber barons were no more.

Malaya became the number one supplier of natural rubber in the world and at its zenith accounted for 60%



of world output. But it was not happy days always. Prices rose during times of high demand and slumped during recession and bad times. British planters strived to maintain a monopolistic position in the market. In the 1920s, immediately after end of WWI, prices slumped. The Stevenson Plan was devised to restrict rubber supply. Prices rose but had the undesirable effect of enthusing neighboring Dutch-held Indonesia and French-held Indochina. They planted more rubber. In

the 1970s and 1980s, as Malaysia industrialized, GDP per capita, increased rubber plantations switched to oil palm and by 1990 Indonesia and Thailand had overtaken Malaysia as top producers.

The story could repeat itself. Indonesia and Thailand, two fast developing countries, could follow the fate of Malaysia as they grow rich. The attached graphs show NR production peaked for both countries and are starting a decline. Even as they complained of low prices, other lower income countries are planting ever more rubber.

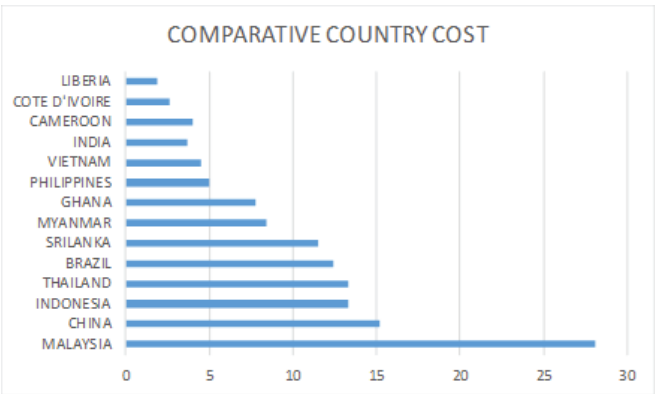
AN ALTERNATE APPROACH TO PRICE

The traditional price model is based on supply and demand. Over the years many more variables have been added: stocks or stocks-to-use ratio, price of oil, price of a basket of synthetic rubbers, U.S dollar exchange, weather, disease, commodity price trends, government action, speculation by unknown investors. A review of the many academic papers on this subject indicated varying degrees of correlation between these variables and price. There is no possibility of assigning cause to effect. The reverse approach, using these variables to predict price has been less convincing.

Rubber economists argue an important difficulty in getting supply right is the long growing period between planting of rubber and start of harvesting. Typically, this is 6 or 7 years. It is difficult to forecast demand that far ahead. This is compounded by fact that 80-90% of rubber is planted by small farmers who instinctively only plant new rubber during times of high prices. Jom Jacob, a rubber economist, argued that new planting overshoots during periods of high prices, and this leads to an oversupply situation when these trees mature. Low prices prevail until demand catches up with the supply overhang. Period of supply shortfall follows leading to high prices and the cycle repeats. Implicit in this scenario is the assumption that supply is relatively inelastic. The conventional view is that smallholders need the income and will increase tapping when prices are low, exacerbating the low-price situation.

Low prices caused hardship among rubber farmers and there is a view that rubber prices are not enough to give farmers a decent standard of living. This also leads to governments ganging together to restrict supply and raise prices or to subsidize farmers to help them make ends meet. This has never worked and in the long run has the effect of making the situation worse.

To explain why, I have to bring back Adam Smith and his concept of “comparative country advantage”. I will argue that Malaysia is no longer competitive and



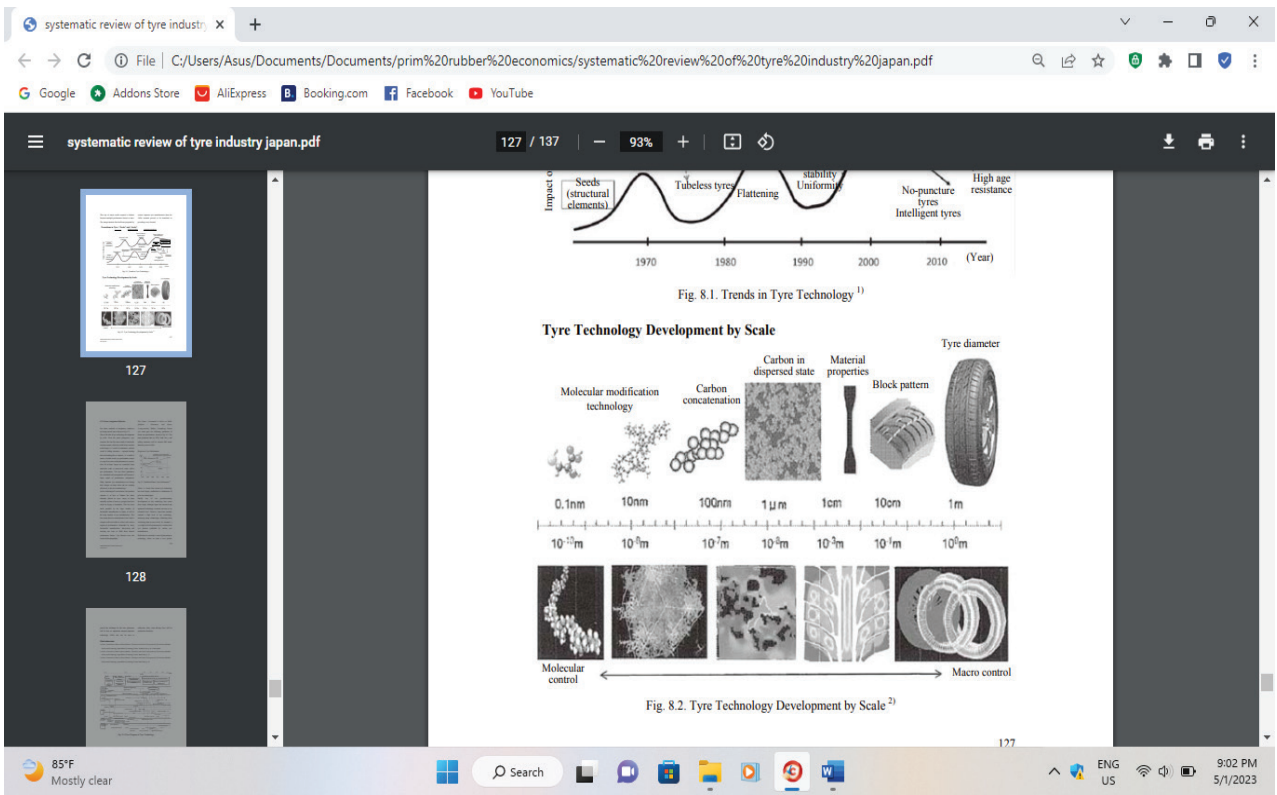
Thailand and Indonesia are at the margin. Look at the graph I have constructed of the relative cost of different countries. I have used a proxy for relative cost (country GDP per capita divided by country average yield of rubber) as actual cost of production is not readily available. Assuming that balancing supply with demand works relatively well for middle term price fixing, for a given demand situation the marginal high-cost farmer needs to stop harvesting to balance supply with demand. Artificially raising prices will encourage more supply from low-cost producers. Similarly, subsidizing farmers to continue tapping will prolong the low price. The better approach is to raise farmer incomes by restructuring the rubber economy via technology (high yielding clones, low frequency automated tapping, improved collecting and novel processing methods), farm ownership reform (size of plots too small), mixed farming, or moving, in part or entirely, to a more lucrative crop. Thailand had the right idea when it announced in 2018 that it planned to reduce rubber area by 20%, raise yields to 2500 kg/ha/

yr and encourage mixed farming. (There are reports that mixing rubber with bee keeping doubles farmers’ income.

DEMAND GROWTH SLOWING

From end of WWII to 1970 world rubber demand (NR + SR) grew at 5-7%. This slowed to a half in the next two decades. Growth picked up in the first decade of the new millennium as China began its love affair with the automobile. Growth has since slowed as the Chinese government reined in pollution and the country moved toward a new mobility model based on public transport, shared mobility, EVs, last mile mobility, A.I. and automation. From 2010-2020 the growth of world rubber demand was between 1%-2% per year. Sale of new cars in China peaked since 2017 and even as demand picked up post Wuhan lockdown, the level of new car demand was below the peak.

Tyres of all descriptions make up 80% of rubber demand in China. The technology development of tyres follows world trends: structurally change tyre construction to use less material (less weight) and enhancing tyre performance for lower rolling resistance, less wear (last longer) and better grip in the wet. The concept is illustrated in the graph which seek improvements in all dimensions (from nano to 1 metre). The motto: reduce, reuse, recycle means less new rubber and more recycled (devulcanized) rubber. It also targets multiple times of retreading of bus and truck tyres. The second concept of going green targets less use of fossil material, more from bio sources.



This slowing of growth of new rubber demand means it will take longer to catch up with the NR supply overhang. In 2018 it was forecasted there will be NR supply shortfall by 2022. This has not happened and David Shaw, a tyre consultant, has projected this will not happen until 2027/28. SR has a different dynamic. Capacity overhang existed pre-covid. Covid accelerated plant closures. There are now reports of shortage of certain grades of SR.

CONCLUSION

As Malaysia, Thailand and Indonesia drive toward achieving developed country status (increasing GDP per capita to USD 25,000) and escape the “middle income trap”, the growth strategy is moving away from labour intensive agriculture and low value-added manufacturing towards more high-tech manufacturing and services. Rubber growing is a labour intensive activity. At current low price of NR the three countries need to restructure the economics of rubber growing to ensure farmers get an adequate income: new technology (high yield planting material, low frequency automated tapping, alternate collection, cheaper processing methods), farm ownership reforms (size of farms too small), mixed farming, alternative /supplementary sources of income. The answer to sustainable NR production in these countries lies in more R & D and effective technology transfer targeted towards achieving these results.

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3. FAO stats.

MALAYSIA: NO MORE #1

In the 1990s rubber estates, responsible for more than half of Malaysia’s rubber output, decided to cut down rubber trees and replace them with oil palm, a more profitable crop. Over a period of a decade or so, the area under rubber owned by estates dropped more than 80% from a peak of over 700,000 hectares. Today, only about 50,000 hectares of estate rubber remained. Smallholder rubber also declined. Production tumbled from around 1.6 million tonnes in the 1980s to 400,000 tonnes today. More than 60% of the estimated 1 mi ha of land planted with rubber are untapped because tappers cannot earn a decent income at current low prices. To achieve the government target income of RM 4,000 a month, the rubber farmer needs to either increase his yield from trees to 2500 kg/ha/yr or increase size of his holding to 4 ha. The average size of rubber holding in W. Malaysia is between 1.5 to 2.5 ha. Due to neglect and low income, yield for a well maintained holding is less than 1500 kg/ha/yr; in many cases, due to low quality planting material and poor management, yields are less than 1000 kg/ha/yr.

A recent report in 2018 by researchers at University of Malaya said 90% of smallholders surveyed in Perak, Negri Sembilan, Sarawak and Sabah did not achieve the RM 4000 target. On the contrary, about half of them are living below extreme poverty or poverty line. “Currently almost all smallholders are low income earners below RM800 per month,” they wrote. Only 36% of their total income is from rubber, “they have to find alternative jobs to sustain”.

There is a shortage of workers prepared to tap rubber. Because of the low income from rubber tapping, it is no longer the main source of income. The rubber farmer works on other jobs and taps rubber to supplement. He taps, perhaps two times a week, on weekends and one weekday morning when he finishes his task early, have a quick rest, then goes to attend to his normal job. To do this, he stops harvesting latex, and go for cuplump instead. This is the reason why Malaysia stopped producing latex. Malaysia is the #1 maker of rubber gloves in the world, yet almost all the latex is imported from neighbouring Thailand and Vietnam.

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AI and future of the plastics and rubber industry in Sri Lanka

Chaminda Perera

Overview of the plastics and rubber industry in Sri Lanka

The plastics and rubber industry is a significant sector in Sri Lanka, contributing to the country's economic growth and development. Sri Lanka's plastics and rubber industry is diverse, encompassing the production of various products such as packaging materials, automotive components, construction materials, and consumer goods.

The industry has been facing challenges in recent years, including competition from other countries, the lack of advanced technology, and inadequate infrastructure. However, the adoption of AI technology presents opportunities for the industry to overcome these challenges and continue to grow.

This article will explore the current use of AI in the plastics and rubber industry in Sri Lanka, the advantages and future applications of AI, as well as the challenges and opportunities for growth in the industry. The goal is to provide insights into the potential impact of AI on the plastics and rubber industry in Sri Lanka and encourage industry stakeholders to embrace this technology to remain competitive and achieve sustainable growth.

Importance of artificial intelligence (AI) in the manufacturing sector

Artificial intelligence (AI) has become increasingly important in the manufacturing sector in recent years. This technology involves the use of algorithms, machine learning, and advanced analytics to automate and optimize various manufacturing processes, resulting in increased efficiency, productivity, and profitability.

One of the main advantages of AI in manufacturing is the ability to reduce costs by identifying areas of waste and inefficiency. AI can analyze large amounts of data from sensors and machines to detect patterns and anomalies that human operators might miss. This enables manufacturers to optimize production processes, reduce downtime, and minimize defects and errors, resulting in significant cost savings.

In addition, AI can help improve quality control by detecting defects in real-time, reducing the risk of

defective products reaching customers. AI-powered quality control systems can also learn from past defects to improve accuracy and reduce false positives and negatives.

Another benefit of AI in manufacturing is the ability to enable predictive maintenance. By monitoring equipment and analyzing data in real-time, AI can identify potential failures before they occur, allowing for timely maintenance and reducing downtime.

Furthermore, AI can help manufacturers improve supply chain management by optimizing inventory levels, reducing lead times, and improving forecasting accuracy. This can result in improved customer satisfaction and increased revenue.

Overall, the adoption of AI in manufacturing has the potential to revolutionize the industry, increasing efficiency, productivity, and profitability. As AI technology continues to advance, manufacturers who fail to embrace it risk falling behind their competitors in terms of quality, cost, and speed.

AI and the Plastics & Rubber Industry in Sri Lanka

The plastics and rubber industry in Sri Lanka is beginning to adopt AI technology to improve efficiency, productivity, and quality control. Some of the current applications of AI in the plastics and rubber industry in Sri Lanka include:

Quality control: AI-powered cameras and sensors are being used to detect defects in plastic and rubber products in real-time. This enables manufacturers to identify and address quality issues before they result in costly returns or rejections.

Predictive maintenance: By analyzing data from machines and sensors, AI can predict when maintenance is needed, reducing downtime and maintenance costs.

Optimization of production processes: AI algorithms can analyze data from sensors to optimize production processes, reducing waste and improving efficiency.

Product design: AI can be used to optimize the design of

plastic and rubber products, reducing material usage and production costs.

Inventory management: AI-powered inventory management systems can optimize inventory levels, reducing the risk of stockouts and excess inventory.

Supply chain management: AI can optimize the supply chain by improving forecasting accuracy, reducing lead times, and optimizing inventory levels.

While the use of AI in the plastics and rubber industry in Sri Lanka is still in its early stages, there is significant potential for further growth and development. As the technology continues to evolve, manufacturers in Sri Lanka are likely to adopt more advanced AI applications, leading to increased efficiency, productivity, and competitiveness.

Future applications of AI in the plastics & Rubber industry

The future of AI in the plastics and rubber industry in Sri Lanka is bright, with many exciting applications currently being developed or on the horizon. Some potential future applications of AI in this industry include:

Intelligent automation: AI-powered automation could enable the development of highly flexible and responsive manufacturing processes, allowing for rapid adjustments to changing customer demands or production requirements.

Predictive quality control: By analyzing large amounts of data from sensors and cameras, AI could predict potential quality issues before they occur, enabling proactive intervention to prevent defects.

Advanced robotics: The integration of AI and robotics could enable the development of highly efficient and flexible manufacturing processes, allowing for the production of complex plastic and rubber products with high precision and accuracy.

Advanced materials development: AI could enable the development of new and innovative plastic and rubber materials with enhanced properties, enabling the creation of new products with unique features and functionalities.

Smart supply chain management: AI could enable the creation of highly efficient and responsive supply chains, allowing for rapid adjustments to changing demand patterns or disruptions.

Overall, the future of AI in the plastics and rubber industry in Sri Lanka is likely to be characterized by significant innovation and growth, as manufacturers seek to leverage the power of this technology to improve efficiency, productivity, and competitiveness.

Challenges and Opportunities Artificial intelligence

Challenges facing the adoption of AI in the plastics and rubber industry in Sri Lanka include a lack of awareness and expertise, cost, and data quality and access. Many manufacturers are not familiar with the technology and do not have the necessary expertise to implement it effectively. The cost of implementing the technology may also be a barrier for smaller manufacturers, while larger manufacturers may be hesitant to take on the risk of investing in untested technologies. Effective use of AI requires access to high-quality data, which may not always be available. In addition, manufacturers may be hesitant to share data with competitors or third-party vendors, making it difficult to develop effective AI models.

Despite these challenges, there are significant opportunities for growth and development in the industry with the use of AI. AI can improve the efficiency and productivity of manufacturing operations, reduce downtime, and improve product quality. By enabling the development of new and innovative plastic and rubber materials, AI can open up new opportunities for product development and growth in the industry. Additionally, AI can improve supply chain management by allowing for rapid adjustments to changing demand patterns or disruptions.

To overcome the challenges facing the adoption of AI in the industry, manufacturers can invest in education and training programs to help employees develop the necessary skills to implement and utilize AI effectively. Collaboration with third-party vendors or other industry players can help address the challenge of data quality and access. Implementing pilot programs to test the effectiveness of AI in specific areas of the manufacturing process before making larger investments can help address the challenge of cost. Finally, the government can provide support in the form of tax incentives, grants, or subsidies to encourage manufacturers to invest in AI technology.

The adoption of AI in the plastics and rubber industry in Sri Lanka presents both challenges and opportunities. By overcoming these challenges and capitalizing on opportunities, manufacturers can improve efficiency, productivity, and competitiveness, leading to sustainable growth and development in the industry.

In summary, the plastics and rubber industry in Sri Lanka stands to benefit greatly from the adoption of artificial intelligence (AI) technology. AI can improve efficiency and productivity, reduce downtime, and enable the development of new and innovative materials, among other benefits. However, challenges such as a lack of awareness and expertise, cost, and data quality and access must be addressed in order for the industry to fully realize the potential of AI.

Looking ahead, the future of the plastics and rubber industry in Sri Lanka with AI is promising. As the technology continues to evolve and become more accessible, manufacturers will have new opportunities to improve their operations and develop new products. The adoption of AI may also contribute to the industry's growth and competitiveness in the global market.

In light of these opportunities, it is important for industry stakeholders to embrace AI technology. Manufacturers should invest in education and training programs to develop the necessary skills to implement and utilize AI effectively. Collaboration with third-party vendors and other industry players can help address challenges related to data quality and access. Government support in the form of tax incentives, grants, or subsidies can also help encourage investment in AI technology.

In conclusion, the plastics and rubber industry in Sri Lanka has much to gain from the adoption of AI technology. By overcoming challenges and embracing opportunities, the industry can unlock new levels of efficiency, productivity, and innovation, leading to sustained growth and development.



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Creating creativity

Some perspectives for Managers

P.P. Perera

Management Counsellor

Creativity is about synthesizing knowledge and experience and the wisdom gained from it, as we go through life. The experience of our daily lives, the ebb and flow of our feelings, our own imagination, our dreams and the world around us are all sources of creativity.

Creativity is a somewhat elusive subject as far as the modern organizations are concerned. My intention here is not delving in to the intricacies, of the subject, but to share some of my observations and views with the readers, which will inspire them to look at creativity from different angles.

When I consider the organizations I have been associated and worked with over the past 54+ years, one salient feature seen is that creativity gets killed, much more frequently than it is supported and nurtured. This does not necessarily imply that the managers have a grudge against creativity and innovation. Creativity is undermined, intentionally or otherwise in everyday work environments that were established to maximize business imperatives such as planning, coordination, control, productivity and most importantly profits.

There was a common saying among the managers in Kenya where I worked in the 80s and 90s, that employees leave their brains in numbered lockers at the gate, when they enter the work arena. I suppose that this could be a universal feature. A notable example is the difficulties that most companies face in implementing 5S practices at the workplaces. Perhaps it could be our natural and inherent tendency about the resistance to change and shifting away from our comfort zones. The irony is that some of the same employees have won the household 5S competitions organized by their children's, schools. On a similar note, I have found, some employees running their own small scale businesses at domestic level with considerable business acumen supported by innovative ideas.

We cannot blame the present day executives for this apparent lack of innovative thinking at workplace, when we consider the demanding expectations placed on them by the top their managements driven by a product and profit oriented approach. Thinking out of the box and developing fresh ideas can feel like a lot of pressure, in



today's competitive and rapidly changing world. Do they have time for inspirational thought or are they driven by circumstances and grappling with the same issues, and problems almost 60% of the working life?

Under the context of the modern day dynamic business scenario, managers very often tend to consider creativity and innovation as having similar meanings. Although the two play key complimentary roles, the subtle difference is that while creativity is the more conceptual part or the "software", while innovation implies a more active role in accrual implementation of the creative ideas, to bring about a positive change.

Creativity is the ability to make or otherwise bring in to existence, whether a new solution to a problem, a new method or devise or a new artistic object or form.

Managerial creativity is the capacity of managers to develop novel appropriate ideas regarding managerial processes and managerial systems.

The Oxford Dictionary describes innovation as the introduction of new things, ideas or ways of doing something. From a business point of view, this implies, the process that an individual or an organization undertakes to conceptualize brand new products, processes and ideas, or to approach existing products, processes and ideas in a new way.

According to Joseph Schumpeter the Austrian political economist (1883-1950), Innovation is **the process and outcome of creating something new, which is also of value**. Innovation involves the whole process from opportunity identification, ideation or invention to development, prototyping, production marketing and sales, while entrepreneurship only needs to involve commercialization (Schumpeter).

We cannot undermine the grave importance of innovation as a strategic driver for business growth, in a world so drastically transformed by almost two years of Covid-19 pandemic. The word "new normal" that entered our vocabulary in the aftermath of the first wave in late 2020, seem to have generated the wrong

signal, as the words new and normal can sometimes be mutually exclusive. Naturally and understandably most companies are resorting to catching up the lost production and markets by focusing on capacity utilization, and improving efficiencies and innovation is skewed towards technology and product development.

What can we do that is different and needed? and how can we reinvent ourselves? These are some pertinent questions that can freeze our minds when trying to force the answers. Developing an "innovative mind" is a skill to have mental creativity, and to approach the world with a fresh and perhaps an unconventional way.

When considering the landmark innovative discoveries and inventions in the history of mankind, one clearly emerging revelation is that the concept of an "original idea" similar to the original sin itself could be a myth, because all new findings are based on the skill and ability to comprehend the cause /effect relationships of the existing information and generating new knowledge. Discovery of fire and the wheel, the inclined plane, steam engine, the conveyor system (with apologies to the other famous inventors and discoverers) were all based on interpreting the existing knowledge and information in a new way. Discovery of Gravity and the Laws of Motion by Newton, the famous equation $E=MC^2$ of Einstein and DNA by Crick and Watson, were all based on expansion of existing knowledge. On a similar note we can understand that the emergence of the great philosophers such as the Lord Buddha is the result of innovative thinking created by the observation, analysis and evaluation of existing knowledge and information.

This is the basic reality that the management and the managers should understand. Innovation is not magic or rocket science. It emerges through our own inquiring and investigating minds. Overlooking this basic truth is the reason for the majority of failures of Elite Groups, Brainstorming Teams, Think Tanks, Focus Groups and Task Forces and other hypes used by some companies today to bring forth productive innovation.

What we should look ant when becoming creative? We cannot visualize a creative tomorrow. We learn from the past and look back at rearview mirror while driving forward, it is important to understand the causal relationship of the past and present to create a better future. Everything in Nature is relative. This applies to we humans and managers as well. Creativity is like a double edged sword, a good servant but a bad master. History is full of examples where creativity has been used and still being used for working nation against nation, race against another, company against a company and man against man.

We should always focus on the positive aspects of creativity, without allowing our likes, dislikes, greed, hatred and delusions to govern us in achieving desired positive outcomes, that are beneficial to the wellbeing of us, as individuals, our family, the employer, the society, our country and the mankind at large,

Anthropologically, it can be seen that the "creative mind "of the modern human as scientists would like to label them started with the evolution of Homo sapiens (Latin "wise man") between 200,000 to 300,000 years ago. The invention of tools and artifacts out of stone, discovery of fire and the wheels at a later stage are all the outcomes of a creative mind, by using observations and the limited information available at the time. Creativity was a tool for survival to enable the human race to perform the vital a tasks **faster, easier and safely**. We cannot see much deviation from these objectives even at this technological and digital age except that **cost effectiveness** has been added

Extensive scientific studies have been done in recent times on creativity of the human mind, covering the anatomical, physiological, psychological and social dimensions. According to a popular view, creativity is the product of the brain's right hemisphere and innovative people are considered "right brain thinkers", while "left brain thinkers are ". The frontal cortex of the brain has long been identified as the hub of creativity, as it seems to be responsible for many functions, that contribute to creative thinking (such as working memory or short term memory). Being creative can increase positive emotions, reduce depressive symptoms and anxiety and improve the functioning of our immune systems

Like in most subjects relate to management, an overwhelming array books, publications and research finding confronts the modern manager who might find it somewhat difficult to navigate. Creative problem solving, divergent thinking, lateral thinking, mind mapping and critical thinking to name a few. Managers should not fall in to the trap of getting carried away and become over defendant on any one of them as it has often happened with quality management, and ICT. ***They are good servants but bad masters.***

Some of the common reasons for the lack of creativity according to my experiences are:

- Fear of blame, ridicule and d the fear of decision making.
- Too many inputs. Information overload. **Too many meetings**

- Not comprehending the “big picture” of identifying the forest and the trees.
- Chasing for perfection and stereotyping.
- Lack of resources and recognition.
- Lack of authority and complacency to stay in the comfort zones

A few practical ways of nurturing creativity at work are recommended as follows:

- Collaborate and draw inspiration from others.
- Focus on the task (**mindfulness**)
- Challenge conformity.
- Show comfort with ambiguity
- Paying attention to details. The PDCA approach,⁵ Why? And looking for the latent causes, which will finally end up with the human factor.
- Striving to eliminate feelings of greed, hatred

and delusion

The modern world needs creativity because problems are not getting simpler. With creativity we stop relying on what has already been done and open our minds to what might be. As problems get more complex, there are fewer examples of how to solve them.

“The sculpture is already complete within the marble block, before I start my work. It is already there; I just have to chisel away the superfluous material.”

— *Michelangelo*

In conclusion, it can be said that we have to look in to our own minds for bringing creativity to the surface to make it useful, to us as individuals, our families, employer or company, the society, the nation and the mankind at large, and we as managers have a key role to play .

“Polymer processing development towards environmental sustainability goals: An Overview”

(Plenary presentation at the 19th Asia Workshop in Polymer Processing 5th – 7th Oct, 2022)

Pak-Kuen Chan, FPRIM

Abstract:

Significant advances of polymer processing technology has been developed and adopted for the manufacturing of a wide array of products to fulfil requirement of our daily lives. Amid the increasing concerns of Climate Change and global warming, a number of approaches are underway to address this concern. United Nations members adopted in 2015 an agenda i.e. “Transforming Our World: The 2030 Agenda for Sustainable Development”. Current and future development of polymer processing should gear towards the compliance of the 17 pillars of the SDGs in combination with IR 4.0 and Circular Economy. The paper presents an overview of polymer processing development which takes into consideration of environmental sustainability amongst others. This includes but not limited to smart manufacturing, green polymers, 3D printing, biodegradable plastics, polymer master-batching, smart polymers and latest development not forgetting environmentally friendly manufacturing process using renewal energy e.g solar, wind, biomass, low carbon footprint and recyclability.

Introduction:

It is recognised that polymer is one of the most significant achievements of Chemistry; and to-date it remain one of the well-researched material. In tandem, marked advances of polymer processing technology has been developed and embraced for the manufacturing of a wide array of products to fulfil requirement of our daily lives. However, existing polymer processing technology previously developed might have overlooked or somewhat ignored the elements of environmental sustainability leading to the generation of abundant wastes e.g. the single-use plastics of which environmental pollution and recyclability being the challenges.

Polymers & Processing principles

Polymers are very large molecules made up of repeating smaller and simple chemicals to form very long molecular chains which are elastic by nature. Some polymers occur naturally e.g. natural rubber, silk etc. while others are man-made e.g. polyethylene, polyamide etc.

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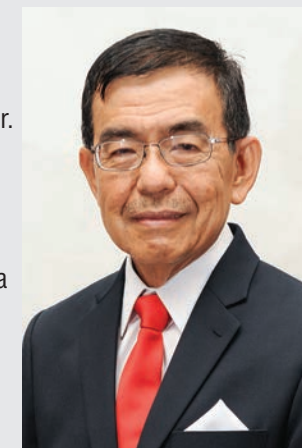
40 + years of technical & operation experience in rubber manufacturing industry starting his career in Revertex Ltd, which is an international rubber latex/polymer emulsion manufacturer. Last employment was Weir Minerals Malaysia (former LINATEX Rubber), a leading global supplier of rubber products for the mining and aggregate industry. Positions held include Divisional head of Research & Technology and Global Rubber Technical Consultant.

Presently working as freelance rubber consultant; part time lecturer at PRIM, Akademi Hevea Malaysia (MRB), and PGRT program at UniKL.

Acquired the Licentiate ship of the Plastics & Rubber Institute (LPRI) London and Master degree in Business Administration (MBA) from University of Strathclyde, Scotland.

Training competency include Dry Rubber Manufacturing Operation under Human Resource Skill Development Department. Also a Certified and Accredited Trainer under Human Resource Development Corporation.

PK was awarded Fellowship of the PRIM and has served as the President of the Institute for 6 terms of 12 years.



Polymers in general are classified as follows:

- Natural Polymers: They occur naturally and are found in plants and animals
- Semi-synthetic Polymers
- Synthetic Polymers
- Linear Polymers
- Branched-chain Polymers
- Cross-linked Polymers
- Classification Based on Polymerization
- Classification Based on Monomers

Polymer Processing

Polymer processing is defined “An engineering activity concerned with operations carried out on polymeric materials or systems to increase their utility” - *Algae Based Polymers, Blends, and Composites, 2017*

Polymer processing technology which is typically undertaken prior to shaping process has shown remarkable progress with the development of synthesis methodologies, materials properties characterization, and their ultimate applications. The bulk of the polymer processing industry is in the production of **films** and **sheets** of thermoplastic polymers. Products are primarily used in the packaging industry for either foodstuffs (groceries, dairy produce, etc.) or other consumer products. There exists a wide spectrum of processing equipment which include Single and twin screw extruders, Injection moulding machine, Batch mixers, Roll mills, Calenders and so on.

Typical polymer Processing Operations

Polymer processing involves all or some of the operations e.g. handling of particulate solids; melting or heat softening; depends on the thermal and physical properties of the polymer (T_g , T_m) degradation temperature; pressurization and pumping; transporting the melt to the shaping operation largely depends on the polymer rheological characteristics; mixing for melt homogenization or dispersion of additives. There are many other operations which include die forming, moulding and casting; secondary shaping (e.g. Thermoforming, blow moulding; calendering and coating processes.

Environmental Sustainability & Concerns

The scope of environmental sustainability for polymer processing is fairly wide ranging but, in general, it essentially incorporates the following practices:

- (i) Effective management of resources;

- (ii) Environmental protection,
- (iii) Waste reduction, and
- (iv) Avoidance of hazardous materials to ensure our future generations of humanity continue to enjoy an acceptable quality of life on earth.

All the above would certainly help in contributing to the reduction of Climate change and Global warming which relates to greenhouse gases emission and environmental pollutants. This is especially critical amid the current natural resources depletion, solid wastes accumulation from both industry and domestic consumption. In recent years, Climate change and Global warming concern have escalated as evidenced by increasing Government and Corporate's focus on environmental sustainability compliance.

Polymer processing: Sustainability Compliance

Current and future polymer processing development shall be guided and governed by several environmental sustainability objectives. Some of which to be discussed as below:

- a. Sustainable Development Goals (SDG)
- b. Industry Revolution 4.0 (IR 4.0)
- c. Environmental Social & Governance (ESG)
- d. Circular Economy

a. Sustainable Development Goals (SDG)

IN 2015, the United Nations adopted 17 sustainable development goals (SDGs) to be achieved in 2030. SDG is an interconnected strategy for the promotion of sustainable practices and solutions. SDGs aim to address pertinent issues as below faced by our society. Two emerging topics i.e. Circular Economy (CE) and Industry 4.0, are currently gaining interest and would contribute to meeting SDG goals.



b. Industry Revolution 4.0 & its relevance

The concept of IR 4.0, first incepted in Germany around 2012, involves technological innovations in

the fields of *automation* and *information technology* for manufacturing. Its basic objective is the creation of faster, flexible and efficient processes; which are clearly relevant to polymer processing development. It further promotes the union of physical and digital resources, connecting machines, systems and assets in order to produce higher quality items at reduced costs. It is necessary to generate a high level of articulation between the main technologies that form the concept comprising the 9 pillars. They are Big Data & Analytics; Robotics; Simulation; Horizontal & Vertical Integration; Internet of Things (IOT); Cyber security; Cloud Computing; Additive Manufacturing and Augmented Reality.



Source: <https://www.dreamstime.com>

IR 4.0 is recognised as a platform for transforming the operation potential of manufacturing industries. In 2018, Hj. Nik Rosdi Nik Yusoff, a director for Productivity & Competitiveness Development of Malaysian Productivity Corporation highlighted a concern: “... **the issue of Malaysia's low productivity growth was of concern to us, as the level of productivity growth was stagnant in 2017**”

Hence, IR 4.0 is to be adopted and embraced by manufacturing sectors which include Polymer processing to boost productivity growth with sustainability compliance.

C. Environment, Social & Governance (ESG)

ESG is a set of standards measuring a business's impact on Environment, Social and Governance; the latter relates to how transparent and accountable it is. In recent years, a number of Malaysian companies were investigated for apparently noncompliance to ESG. Their products were held up at US ports by the US Customs and Border Protection (CBP) on allegation of “forced labour” or excessive overtime in their production. One oil palm plantation group was also blacklisted for alleged infringement to environment sustainability associated with de-forestation, rightly or wrongly!

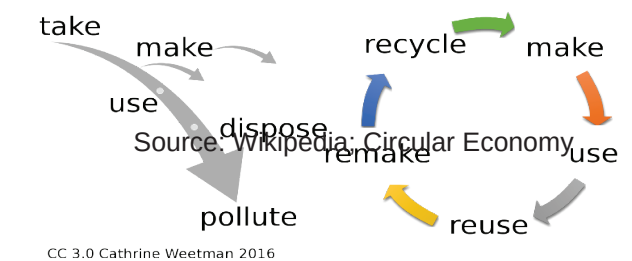


While SOCIAL which covers diversity, equity, human rights & labour standards, good health/wellbeing etc. and Governance which focuses on reporting and Transparency etc., ENVIRONMENT encompasses **Sustainable Ecosystem, Waste Management, Water Management & Efficiency, Responsible Consumption & Production, Renewal Energy, and Energy Efficiency**

ESG is increasingly relevant to polymer processing in terms of Capacity building initiative, which is key factor driving the journey towards a sustainable economy. The adoption entails a multi-disciplinary approach to research program, new technology, R&D upscaling.

d. Circular Economy

Polymer processing approach towards Circular Economy is transformed from Linear Economy which is designed with little concern of ecological footprint. The figure below is an illustration showing the difference between the ‘take – make - waste’ of Linear Economy practice and the Circular Economy approach covering “**make – use – reuse -remake – recycle – make**”



The model of production and consumption involves sharing, leasing, re-using, repairing, refurbishing and recycling existing materials and products as much as possible. This in turn aims to tackle global challenges associated with climate change, biodiversity loss, wastes and pollution. Hence, the core values encompass:

- eliminating waste and pollution
- circulating products and materials
- regeneration of nature

Carbon Border Adjustment Mechanism (CBAM)

CBAM is another environmental practice need to be brought into attention during polymer processing development. EU has recently extended this climate change initiative to the rest of the world by putting a price on imports to reflect the Carbon embedded in them. It is a proposed carbon tariff on **carbon intensive products**, such as cement and some electricity, imported by the European Union. The transition to a low-carbon economy requires technology and investment beyond

the resources of many countries. Proposed solutions include technology transfer and Green Finance. Presently CBAM appears to have no immediate impact on polymer sector, but all future development needs particular focus on CBAM compliance.

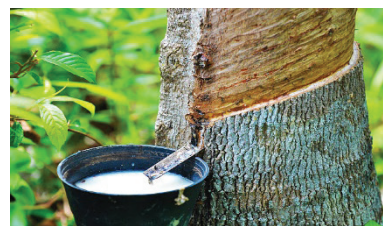
Polymers: Go Green, go Natural !

There are essentially two classes of sustainable polymers i.e. **Natural** and **Green** polymers. Although both appears synonymous, there are some differences:

Natural Polymers:

Natural polymers exist naturally or are produced by living organisms (such as cellulose, silk, chitin, protein). They can also be man-made out of raw materials. However, it was reported the amount is less than 1% of the 300 million tons of plastics produced per year despite production is steadily rising driven by market demand for a variety of applications.

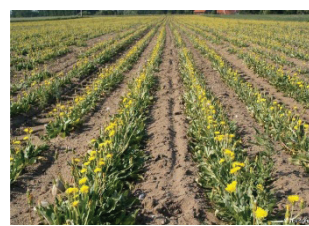
One most notable “Natural Polymer” is Natural Rubber derived from *Hevea Brasiliensis* (1.4 cis polyisoprene). NR is a well-recognized renewable resourceS par excellence. NR plantation is a carbon dioxide sink and a carbon dioxide scavenger. Enormous quantities of CO₂ are emitted during the manufacturing process using petroleum-derived synthetic rubber as the raw material especially for car tires manufacturing. Replacement with natural rubber would confer low carbon footprint that prevents global warming. Other NR alternatives being looked into by major tyre manufacturers include Guayule, Russian dandelion, Gutta Percha, Balata etc.



Hevea Brasiliensis



Guayule



Russian Daendelion field

Bio-based polymers which could be classified a Natural Polymers are defined as materials of which at least a portion of the polymer consists of material produced from renewable raw materials. For example, bio-based polymers may be produced from corn or sugarcane. The remaining portion of the polymers may be from fossil fuel-based carbon. Bio-based polymers generally have a lower CO₂ footprint and are associated with the concept

of sustainability. For example, a most recent report that a Japanese sports gear maker, Asics, has successfully developed sneakers made with plant-based polymers which contains the lowest carbon footprint with reduced carbon dioxide emission of 1.85 kg of CO₂ during their lifetime. (Ref: Nikkei – 09 Oct, 2022)

• Green Polymers

Green polymers are produced using green (or sustainable) chemistry. Green chemistry relates to the “*design of chemical products and processes that reduce or eliminate the use or generation of substances hazardous to humans, animals, plants, and the environment*” (IUPAC 1990)

Hence, polymer processing shall fulfil the green principles which include a high content of raw material in the product. The production must be clean and generate zero waste coupled with low carbon footprint without the use of additional substances e.g. organic solvents. It should incorporate high energy efficiency during polymer manufacturing and absence of health and environmental hazards.

Bioethanol is considered an example of a Green Polymer. It is an emerging biofuel, produced by fermentation of sugar obtained from sugar cane or cellulose; and also a versatile raw biomaterial for production of olefin and di olefin monomers, including ethylene, propylene, and butadiene

Smart Manufacturing

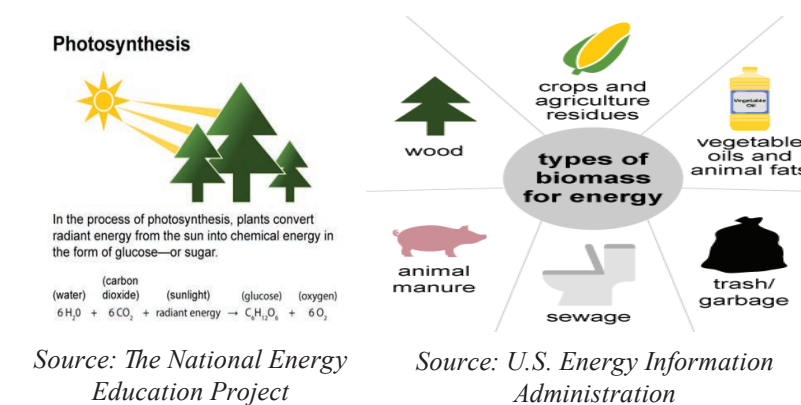
Smart Manufacturing is a broad category of manufacturing with the objective of optimizing concept generation, production, and product development. As mentioned earlier, IR 4.0 is a tool which drives towards Smart Manufacturing. The interaction of IR 4.0 and Smart Manufacturing contribute to a fully integrated, collaborative manufacturing system which respond in real time in operating condition, supply network and customer needs. Further, it tends to drive innovation, technology and human creativity addressing:

- Wastes reduction
- Reduction of energy consumption
- Minimising environmental impact via reduced

energy consumption aiming increased productivity

Biomass—renewable energy

Biomass is commonly derived from organic material that comes from plants and animals. This was used to be the largest source of total annual U.S. Energy Consumption and today remains net exporter of biomass energy. Biomass energy continues to be an important fuel in many countries and helps mitigate the effects of climate change. Biomass provides excellent feedstock for the synthesis of useful **monomers**. Sustainable polymers from biomass can be obtained through chemical modification of natural polymers, such as **starch, cellulose, or chitin**



3D Printing for Polymer Processing

3D printing, also known as Additive Manufacturing, is one of the 9 pillars of IR 4.0. This is a technology of creating a three dimensional object layer-by-layer using a computer created design. It is described as an additive process whereby layers of material are built up to create a 3D part. As compared with Subtractive Manufacturing process i.e. final design is cut from a larger block of material. Hence, 3D printing creates less material wastage. Other advantages include Flexibility and Creativity during designing process. However, current limitations include being not conducive for mass production nor suit every type of manufacturing technique. Furthermore, hardware & materials are at present relatively price prohibitive.

A study on Fused Deposition Modeling (FDM) has recently been undertaken by Malaysian Rubber Board, presented at recent RubberCon 2022 by Dr Yen Wan Ngeow (Roland), Senior Research Officer. Project objective is, in summary, to evaluate the effect of infill densities and patterns of Thermoplastic Polyurethane (TPU) in comparison with conventional compression molding process

It was reported **4D applications** arising from 3D printed objects are the new normal for Additive Manufacturing technique as researchers are focusing on exploration of smart material matrix to address different targeted applications such as for drug delivery, sensor applications and self-assembly applications etc (Gao *et al.*, 2016; Kumar *et al.*, 2020b)

Polymer master-batching

Master-batches or polymer bound additives are commonly used in polymer processing. This entails the incorporation of color pigments, additives and antimicrobials into the polymer resin or other liquids. Concentrated mixture of an additive is encapsulated in a carrier material or binder, such as PE or PP. The benefits include safe handling of hazardous materials, cleaner production, easier addition of ingredients, product and process consistency, consistency and stability. While the material costs are relatively higher than the powder counterparts, there is strong justification using polymer bound additives for future polymer processing for cleaner and safer operating environment with reduced chemical loss.



Smart Polymers

Smart polymer embraces a wide range of different compounds that can change their color, transparency or shape in response to their environment. They are smart because of their ability to respond in significant way when small environmental changes are detected.

It only takes a small variation in temperature, humidity, pH, or light, for example, to induce a large change in smart polymer properties, and this non-linear response makes them unique. Smart polymers may fall into one of three groups:

- **Physical** – temperature, ultrasounds, light, or mechanical strength.
- **Chemical** – pH and ionic strength
- **Biological** – enzymes and biomolecules



Renewal Energy

“Renewable energy is energy that is collected from renewable resources that are naturally replenished on a human timescale. It includes sources such as sunlight, wind, the movement of water, and geothermal heat” – Wikipedia

Manufacturers are increasingly developing new ways of using renewable energy to strengthen clean energy competitiveness in various industries. One of which is *polymer composites in Wind Energy application e.g. wind turbine blades*, which are light and robust replacing the metal counterparts and hence significant energy saving.

Biodegradable plastics

Plastics are ubiquitous in our daily lives but not easily biodegradable and hence posing threat to environment and our health. Biodegradable plastics degrade into water, carbon dioxide, and biomass in given time frame causing generation of micro-plastics which ultimately harm aquatic life when discharged into ocean. However, not all bioplastics are completely biodegradable. An example of a non-biodegradable bioplastic is bio-based PET. Presently, a relatively small percentage of biodegradable plastics of total global production being produced, which include Oxo-degradable and Hydro-degradable.

Biodegradable polymers are poised to revolutionize from food packaging to medical devices. Some commercial biodegradable plastics are polybutylene adipate terephthalate (PBAT) and polyvinyl alcohol (PVA).

There is another category known as Photodegradable plastics which is copolymer of ethylene with carbon monoxide. They contain ketone groups that absorb sufficient energy from sunlight to cause extensive polymer chains shortening or scission.

Disruptive Technology

Last but not least, Disruptive Technology is something that cannot be ignored by technologists and engineers in future polymer processing aiming environmental sustainability. This is essentially a revolutionary approach that significantly alters the way that consumers,

industries, or businesses operate. It leads to new and enhanced technology that displace

established practices, rendering them obsolete. This leads to creation of new products, processes, new market and new ways of conducting business. There has been a number of Disruptive Technology in recent years e.g. 3D Printing, 5G, Improved Connectivity, Artificial Intelligence and Machine Learning, Automation and Robotics. Most notably disruption being taxis having been replaced by E-Hailing not forgetting E-Commerce which partially substitutes traditional retailing business, if not completely in the future.

My limited experience in Disruptive Technologies for rubber product manufacturing are briefly described herewith:

- a. Manufacturing of Conveyor beltings or rubber sheeting of continuous length.

Conveyor belting and rubber sheets of continuous length are traditionally produced using Compression Moulding press which employs Step-Curing protocol. This has been replaced by, initially, Rotor Cure and later the “Double Belt continuous curing press” which incorporates a “roller carpet” technology first patented in Germany.



VS.

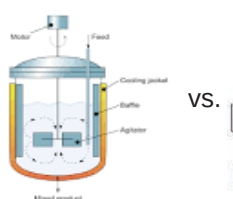


Tradition Compression Press

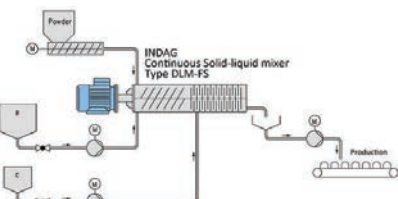
Source: Simpelkemp Double-Belt Press for continuous curing

- b. Continuous mixing of Liquid to Solids or Liquid to Liquid replacing Batch Mixing process.

Batch Mixing



VS.



Source: INDAG Continuous mixing of liquid-solids compound

Outlook

Future polymer technologists/scientists need to define/

predict the complex inter-relationships between process equipment, operating conditions, micro- or macro-structure arising from polymer processing. They need to acquire further understanding of engineering principles e.g. transport, mixing, solid mechanics, rheology), polymer physics & polymer chemistry to accomplish any designated tasks; while ensuring the availability of improved computer-aided design software for:

- mould or screw design cavity filling simulation,
- flow calculations and process simulation

Multicomponent polymer systems (blends, alloys and composites) are expected to continue expanding the horizons of product concepts and novel applications during the next decade.

Conclusion

Escalating environmental concerns e.g. Global warming and Climate Change, warrant Polymer Processing development to adopt a holistic approach by embracing SDGs, IR 4.0 and ESG. SDGs encompass Circular Economy and Smart/Sustainable Manufacturing which contribute to waste reductions, lower carbon footprint and hence environmental protection. In line with such practices and compliance, polymer processing plants, if not already done so, need upgrading to meet future environmental challenges and requirements e.g. use of feedstock of more environmentally friendly and renewable

resources. Polymer technologists need to continuously innovate by observing Disruption Technology that could displace existing technologies rendering them obsolete. They must be sufficiently competent to define and predict the complex interrelationships of every aspect of Polymer Processing development towards environmental sustainability goals.

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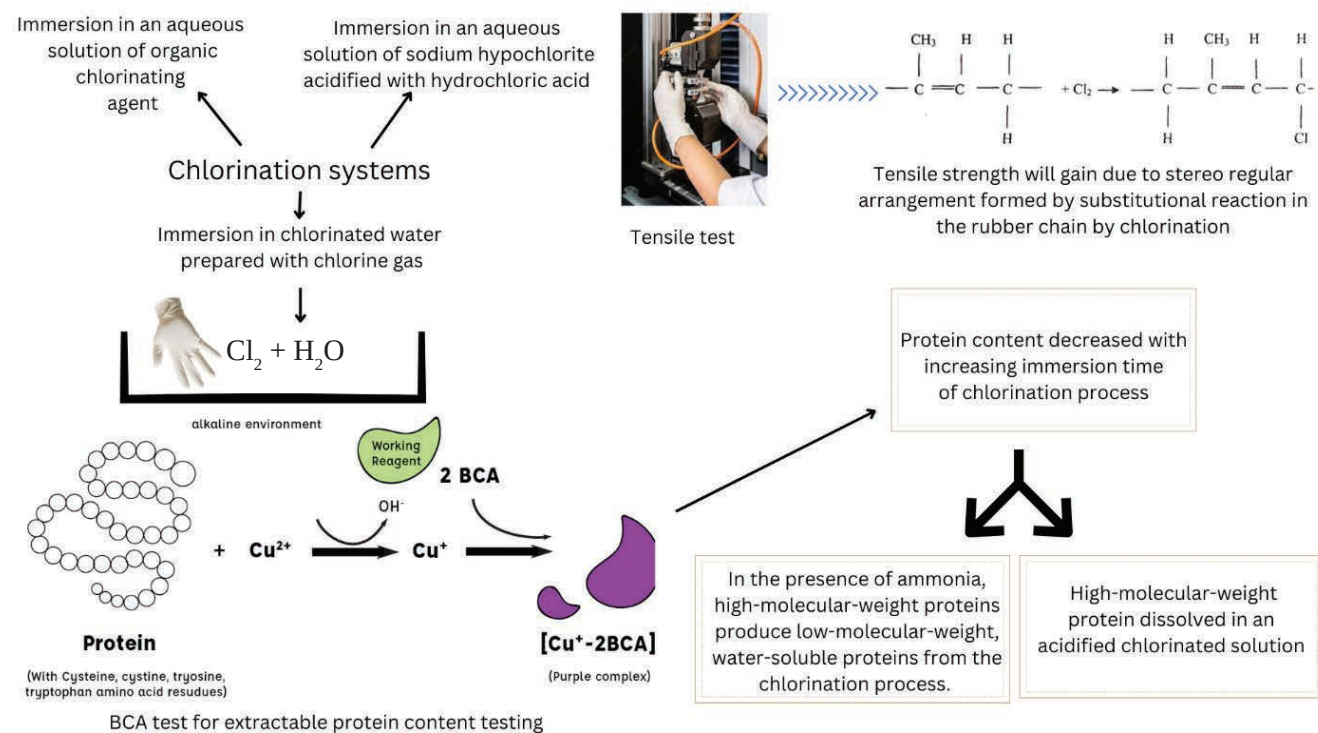
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The effect of chlorination on tensile strength and extractable protein content of surgical gloves from natural rubber latex

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1. Introduction

Natural rubber is made from the latex sap found in the bark of rubber trees (*Heavea brasiliensis*). The rubber is composed of cis-1, 4-polyisoprene (with 4% trans structure in the polymer backbone). Latex is a stable polymeric substance dispersion in an aqueous medium. It is composed of negatively charged rubber particles dispersed in an aqueous medium. Sugars, lipids, proteins, fatty acid soaps, amino acids, and a variety of organic and inorganic salts, including soluble salts of calcium, magnesium, and alkali metals, make up the aqueous portion, or serum. Natural rubber latex has inherent characteristics such as high flexibility, strength, and tensile strength¹.

Glove manufacture accounts for the majority of latex usage². Gloves are initially coated by dipping into a chemical coagulating agent; this process is called

"coagulant dipping," which is the major method used in glove manufacture³. Different gloves are used for various purposes. Among these are industrial gloves², domestic gloves, examination gloves, and surgical gloves. It includes both disposable and non-disposable versions of gloves. Non-disposable surgical gloves are meant to be reused; disposable gloves are meant to be used just once. Examination and surgical gloves are in the disposable category. The usage of surgical gloves by healthcare professionals keeps their skin, free of viruses and body fluids contamination³.

Natural rubber latex and synthetic rubber latex can both be used to make disposable surgical gloves³. Natural rubber latex has superior properties to synthetic rubber latex. Disposable natural rubber surgical gloves come in two types. They are powdered disposable surgical gloves and powder-free disposable surgical gloves. Some healthcare workers are unwilling to wear

powdered gloves due to various allergic reactions to the powder⁴. As a result, the production of powder-free surgical gloves began.

Chlorination of gloves has become more common as a more long-lasting technique of lowering the inherent tackiness of natural rubber latex when contrasted to utilizing powder as a dusting lubricant. When natural rubber latex proteins from powdered gloves are discharged into the air, those who are allergic to them may experience major difficulties^{1, 5}. Although these proteins in the finished glove pose little risk to the general public, certain groups, such as healthcare professionals, spinifida patients, and industrial workers, are at a higher risk of developing these allergies⁶.

Surface halogenation in powder-free gloves is the most effective method for reducing surface friction and tackiness in NR latex films. It is a common process used in the manufacture of surgical gloves and offers a smooth feel, easy donning, and removal capabilities. Vulcanized rubber is softer than halogenated rubber. The three main methods of surface halogenation are chlorination, bromination, and iodination³.

The best surface treatment is chlorination because it reduces surface tackiness and friction better than other halogens. It results in a microtextured film. The surface of micro-roughened gloves appears to have been lightly sanded, which adds a good amount of grip to these gloves. Chlorination was discovered to reduce proteins that can be extracted and excessive accelerators removed from the glove surface¹. The chemical resistance of the glove film can also be enhanced by chlorination. Unless it is not excessively chlorinated, the qualities of the glove film increase without affecting the bulk properties.

In the manufacturing process of disposable surgical gloves made from natural rubber, chlorine is used for the surface halogenation of NRL. The interaction of the halogen with the olefinic double bonds of the natural rubber latex macromolecule results in the formation of a layer of halogenated rubber. Natural rubber that has been vulcanized is softer than rubber that has been halogenated. Hence, the coefficient of friction of halogenated natural rubber is lower. The surface obtained from chlorination is described as microtextured².

2. History of Chlorination

Reducing tackiness, and increasing lubrication are the main objectives of the chlorination process. Initial research related to chlorination treatment was done by G.F.Bloomfield in 1943-1944. To broaden knowledge and research of the chlorination process, great service

was rendered by G.Kraus and W.B. Reynolds (1950), Gorton, Bratby, and Vanderbilt.³

2.1 Chlorination Systems

There are three different ways of chlorination.

- Immersion of the glove in an aqueous solution of sodium hypochlorite acidified with hydrochloric acid².
- Immersion of the glove in an aqueous solution of an organic chlorinating agent².
- Immersion of the article in chlorine water prepared by dissolving chlorine gas (from cylinders) in water².

They show quick reactions and reaction mechanisms are assumed same.

2.1.1 Aqueous solution of an organic chlorinating agent

N-Chloro sodium dichloroisocyanurate is the commonly used organic chlorinating agent.

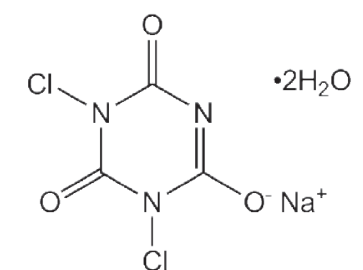
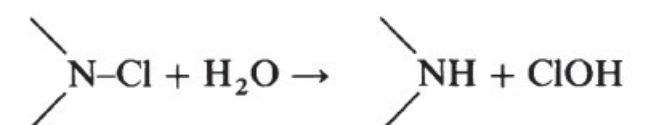


Figure 1: Structure of N-Chloro sodium dichloroisocyanurate¹

This substance, also known as sodium 1,3-dichloro-5-triazine-2,4,6 (1H,3H,5H)-trione, is a disinfectant used to purify water (Figure 1). This can be applied both with and without acid. The ideal acid to use with this is hydrochloric. After the N-Cl is hydrolyzed, the process will produce hypochlorous acid (Figure 2).



Hypochlorous acid reacts with HCl and it will generate chlorine. The rate at which the N-Cl bond breaks down will determine how well chlorine may interact with rubber².

2.1.2 Chlorine water prepared with chlorine gas

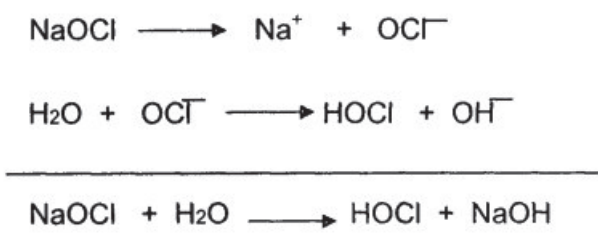
The chlorine gas available in pressurized cylinders is passed into the water until it is saturated with chlorine. Stainless steel is used to construct the saturation tank.

The concentration of chlorine is 0.56% of the weight of water when it is completely dissolved. Water will be used to dilute chlorine to the necessary concentration level. The latex item is then dipped in the chlorine solution for a predetermined amount of time. According to Vanderbilt, 4.5–7.5 min of immersion time is needed, and according to Bratby, 15–30 min are needed for a 0.08%–0.12% chlorine solution. However, different industries have their own chlorine systems, with proper concentrations suitable for their products.

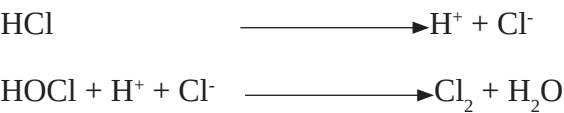
It is somewhat difficult to handle and maintain this system. It needs expensive and high-quality machines. Since chlorine is a toxic gas, there should be extractions and proper ventilation when using gaseous chlorine.

2.1.3. The aqueous solution of sodium hypochlorite acidified with hydrochloric acid

This is the most basic method used in chlorination. According to Gorton and Pendle, 1% m/m of conc. hydrochloric acid is added to a 7.5% m/m solution of sodium hypochlorite.



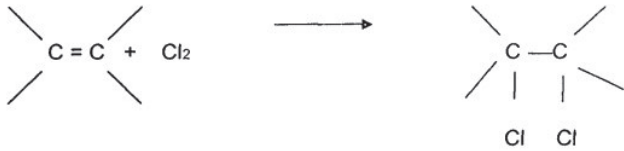
In the presence of HCl,



Not only molecular chlorine solution it also consist of chloride anions, hydrogen ions, hypochlorus acid as well as hypochlorite anions. They are in an equilibrium² having $3 \times 10^{-4} \text{ mol}^2 \text{ dm}^{-6}$ at 25 °C. 0.08 mo dm^{-3} will be chlorine concentration of saturated chlorine water under atmospheric pressure and normal temperature².

There are three potential mechanisms exist for chlorine to interact with rubber molecules.

1. Addition reaction



2. Substitution reaction



Since hypochlorous acid is formed, an addition reaction will happen to give chlorohydrin².



Thermal stability is minimized due to chlorohydrin. According to Kraus et al. chlorination will happen in three steps at 30 °C.

- First step – Substitution occurs
- Second step – 1.2 molecules of Cl react by both substitution and addition reactions
- Third step – 2.2 molecules of chlorine per isoprene unit have reacted by the addition reaction

All subsequent reactions happen by substitution via UV catalyzed addition reactions and oxygen or peroxides catalyzed substitution. In this system, aging properties and thermal stability are less. Surface tackiness reduction and discoloration is not good as chlorine gas system.

Table 1 shows the advantages and disadvantages of chlorination.

Table 1: Advantages and disadvantages of chlorination

Advantages	Disadvantages
Powder free treatment	Inadequate thermal stability
Reduction in protein content	Poor anti-aging properties
Can be done in larger scale	Brittle surface
Less time consuming	Undergo discoloration
	Health hazards due to chlorine gas
	Environmental problems

3. Effects of chlorination on properties

The extractable protein content has been found to be lower after the chlorination treatment. More reduction will result from higher chlorine treatment. After chlorination, surface friction and tackiness decrease, increasing surface lubrication. The level of chlorination has an effect on tensile strength as well. Surface cracks have been discovered to appear at a specific chlorine concentration. Higher chlorine concentrations cause more surface cracks, which lead to leaks and damage the gloves' barrier properties. Depending on their needs, industrialists perform chlorination treatment at various levels. As a result, the glove's quality varies.

3.1 Effect on tensile strength

Tensile strength is the amount of force required to stretch a medical glove until it breaks. Amarasiri¹ tested 36 dumbbell-shaped latex films for tensile strength after immersing them in 6 different chlorine concentrations: 1700 ppm, 1500 ppm, 1400 ppm, 1300 ppm, 1150 ppm and 1000 ppm. The duration of the immersion varied as well: 0 minutes, 4 minutes, 8 minutes, 12 minutes, 16 minutes, 20 minutes, and 24 minutes. He has identified an increase in tensile strength in chlorinated samples compared to unchlorinated samples. According to Blackley³, the tensile strength of post-vulcanized samples ranges from 22 MPa to 38 MPa. The maximum tensile strength was observed in the 1150 ppm chlorine concentration for 12 minutes¹, considering the immersion time in the chlorine bath and chlorine concentration. The relevant tensile strength was 31.746 MPa. As the leaching time increases, tensile strength of the latex film increases⁷. Leaching removes non-rubber substances from the film's rubber particles, improving inter-particle integration. In addition it was identified that the tensile strength values also vary according to the stereo regularity of the rubber hydrocarbon.

Figure 3 shows the reaction between one chlorine molecule and isoprene unit³.

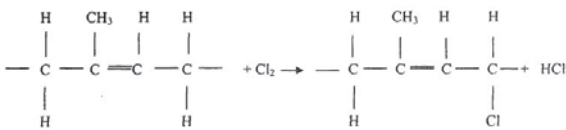


Figure 3: Reaction of rubber molecule with chlorine

The stereoregularity of the polyisoprene structure is distributed as a result of the introduction of chlorine groups into the main chain. This reduces strain-induced crystallinity, which in turn reduces tensile strength¹. The tensile strength of the 12-minute sample increased

dramatically¹. As a result of the continuous substitution reaction, more chlorine groups are introduced into the polyisoprene main chain. This results in a stereoregular arrangement, which improves the strain-induced crystalline structure and other properties of the polyisoprene main chain. The tensile strength of chlorination begins to decrease at 16 minutes. The crystallization reaction has been discovered to occur during the initial substitution. The substitution reaction causes an increase in acidic behavior. Kraus at el. ⁷, and Gorden M.⁸ proposed the following crystallization reaction (Figure 4). The distribution of stereo regularity in the cyclohexane ring reduces strain-induced crystallization and, consequently, tensile strength¹.

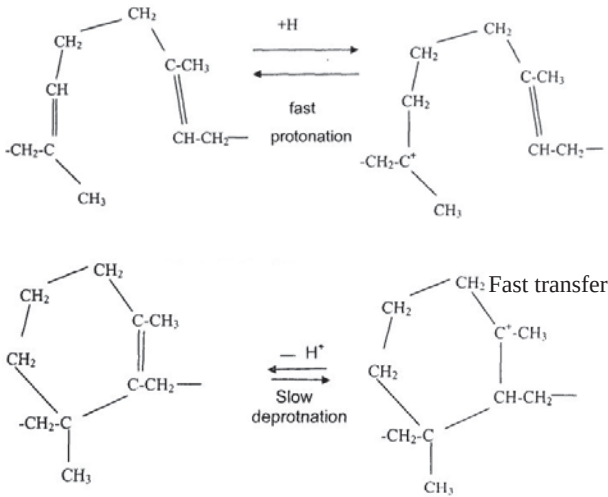


Figure 4: Proposed crystallization reaction¹

3.2 Effect on extractable protein content

There are different methods to test extractable protein content in NR gloves. Because it is simpler and less complicated, the BCA-enhanced protocol method was used to determine the extractable protein content in the majority of previous research. Furthermore, this method is preferred by more manufacturers for measuring protein content, which can reach 50 ug/g. This method has identified the the number of peptides, nanomolecular structure of proteins, and the presence of four amino acids as being responsible for color formation.⁹

Ananda Amarasiri¹ has tested film immersed in an 1150ppm chlorine concentration bath for different immersion times (0 mins, 4 mins,8 mins,12 mins,16 mins,20 mins,24mins). He discovered that the protein content decreased with increasing immersion time. More water-soluble and insoluble proteins will be removed from the surface with a longer chlorination time¹. Allergens, such as hevein, has a low molecular weight and dissolve easily in water at all pH levels³. Some proteins with high molecular weight, such as

alpha globulin, do not dissolve in distilled water but they dissolve in acid, neutral salt, or alkaline solutions³. In ddition, these proteins dissolve more easily in the acidified chlorinated medium than in distilled water.

A successful double-leaching process can reduce proteins by up to 50 microgram/g. All of these proteins are water-soluble. Water-insoluble proteins dissolve in human sweat after being worn, because human sweat contains salt. An allergic reaction could result from the dissolved protein that surrounds the powder particle being absorbed¹⁰. The double-leaching system cannot remove these types of proteins. However, they can be removed with an acidic, alkaline, or neutral salt solution. Furthermore, when exposed to ammonia, a preservative, these high molecular weight proteins disintegrate to form water-soluble low molecular weight proteins¹¹. To avoid protein allergy issues, it is critical to remove both water-soluble and water insoluble proteins. It is identified that the chlorination is the best solution for removing both of these proteins¹.

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Comparative Study of Alternative Solvents for Grip Designing Process of Natural Rubber Latex Coated Glove Manufacture

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Abstract

An investigation and comparative study of alternative less toxic organic solvents for xylene in the grip designing step of the natural rubber latex-coated glove manufacturing process was carried out. In the grip designing step, organic solvents are used to create a crinkled surface on the natural rubber latex coating on the supported glove. The toxic nature of xylene which is the solvent currently in use is the main reason for this exploration. Finding an alternative less toxic solvent instead of xylene is crucial for enhancing the health and safety of workers. Acute toxicity parameters such as lethal concentration (LC₅₀), median lethal dose (LD₅₀), and other evidence like exposure limit (PEL and OEL), and carcinogenicity of each selected solvent were comparatively studied. n-heptane, n-hexane, and ethyl acetate were selected as less toxic alternative solvents which can be used instead of xylene for this process. The swelling capability of each selected solvent was studied by doing swelling index tests with each maturation level of LC 601 and LC 606 natural rubber latex types. According to the results, aliphatic solvents (n-hexane and n-heptane solvents) indicated more effective responses with xylene than other selected solvents.

Introduction

The grasping of something is one of the main purposes of a glove product. Therefore having a proper grip is very important in glove products. Especially industrial safety gloves provide good hand protection for the user in their working environment. So the grip designing step is a very important part of the natural rubber latex-coated glove manufacturing process. There are a few major grip designing techniques that are used in the modern hand protection glove manufacturing field such as smooth surface, sanded over-dip, crinkled surface, and textured surface. Making a crinkled surface on the glove coating by solvent dipping method is very

popular among them because of its economical and operational effectiveness. In this step, a volatile organic solvent that mixes with acetic acid is used to make a crinkled surface on the latex coating. Solvent swelling of natural rubber is the scientific phenomenon that has to be used for this procedure ¹. These crinkles make a rough surface and provide a better grip for the consumer. Industries use various kinds of organic solvents for this grip designing technique. Commonly, aromatic organic solvents like toluene and xylene are the most popular chemicals in this process (Xylene is the solvent that they use currently in the industry). But important attention should be paid to the fact that the toxicity level of aromatic organic solvents is very high. Moreover, these chemicals may have a high risk for lung cancers². When these aromatic ring structures enter the human body cells, they are misconceived as the bases of nucleotides. It can induce DNA mutations and these mutations may eventually lead to cancer³. In the industrial environment, employees are exposed directly to these solvents during their working hours and it may directly impact their health. Therefore using these aromatic chemicals may directly impact human health. As enhancing the health protection of the employees is the main objective of this research, the exploration of the proper alternative organic solvents with low toxicity levels and comparing the solvent’s behaviors with the current solvent creates a good approach to finding the best alternative solvents for this process.

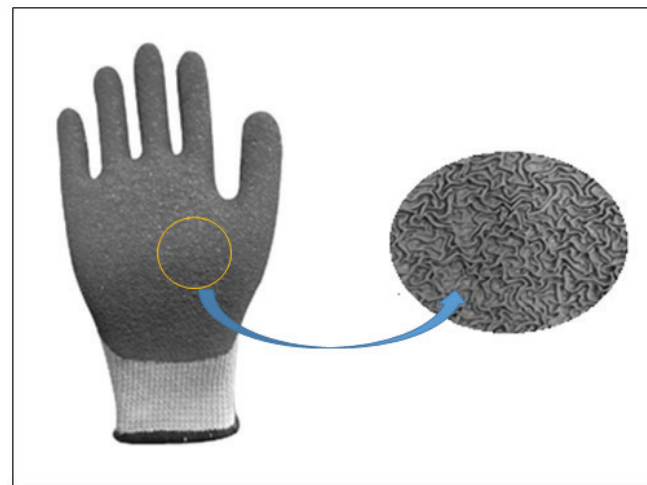


Figure 1: Crinkled surface on the latex coating.

When considering the processing steps of the supported glove manufacturing process shown in figure 2 consist of three main dipping sessions. Pre-coagulant dipping is the 1st dipping session and the shell was immersed in a mixture of calcium and methanol. Then the shell was dipped into the natural rubber compound called compound dipping. Finally, the compound-coated glove was dipped into the solvent bath which consisted of a solvent and acetic acid mixture. This is the grip designing part of the supported glove.

When observing the swelling ability of organic solvents with NR latex compound, the maturation level and the maturation period are very important factors in the glove manufacturing process. After adding vulcanizing agents and other ingredients, the compounded NR latex is matured allows for maturing for a certain period (2-3 days). Before using the NR compound, the maturity level was checked. When the maturation level is increased, the swelling ability is decreased due to the increasing of the crosslinking density. Table 2 shows that the maturation levels and the features of NR coagulant. In the industry, the chloroform test that use to predict the maturation level of natural rubber latex after compounding. The levels are checked according to the elastic ability of the rubber coagulant. The maturity level indication includes 9 levels.

Table 2: Maturation levels of NR latex coagulant

Level	Feature of the coagulant
1. Level 2	The coagulant is stuck in the hand and the elasticity is very high.

2. Level 3 one new	The elasticity is not very high, the coagulant can be flatted properly.
3. Level 3 one	
4. Level 3 one old	
5. Level 3 two new	This level is the quality level that can be used to make glove products. The coagulant is cleaved quickly.
6. Level 3 two	
7. Level 3 two old	The coagulant is not elastic furthermore. After adding chloroform, the coagulant will be crumbled.
8. Level 4 one and Level 4 two	

The swelling capability of selected less toxic solvents was determined under different maturation levels.

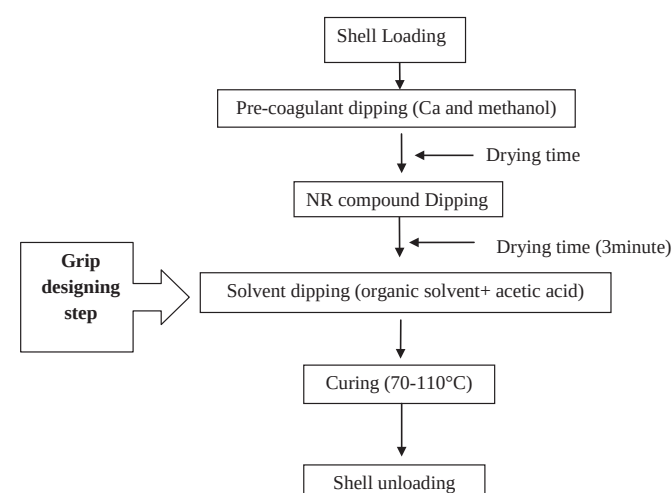


Figure 2: Processing steps of NR supported glove manufacture

Methodology

The molecularly and thermodynamically compatible solvents with natural rubber were investigated, and secondary sources were used for this. When a solvent is selected for a relevant polymer, the chemical structure, interactional compatibility, and thermodynamical closeness are the major factors should be concerned. Natural rubber is a non-polar polymer, so it will dissolve or swell with non-polar solvents as well. Hence, it is important to study non-polar solvents that are compatible with NR. The solubility parameter models could be used for finding thermodynamically compatible solvents with NR. Finally, common and non-polar solvents which have the closest solubility parameters to NR were investigated. Then The solvents which are selected by

the above step were compared for toxicity. The acute toxicity of the solvents is the main factor in this study. Acute toxicity parameters like LC_{50} values, LD_{50} values, and other toxicity parameters such as PEL, OEL values, and carcinogenicity of the solvents were evaluated by comparing them with the current aromatic solvent

(m-xylene). Finally, the swelling capability, swelling time, and crinkle formation ability were identified by using selected less toxic solvents. According to the toxicity evaluation results, hexane, heptanes, and ethyl acetate were identified as the less toxic solvents which are suitable for the grip designing process.

Results and Discussion

Table 1: Toxicity evidences of selected solvents ^{4,5,6}

Solvent	LD_{50} (mg/kg)	LC_{50} (ppm) 4h (Rat)	PEL for 8 hours work shift (ppm)	OEL for 8 hours work shift (ppm)
Xylene	3523- 8000	6700	100	50
Hexane	25000	73500	500	20
Cyclohexane	>5000	>32.88	300	200
Heptane	>5000	17937	500	500
pantane	>25.3	3000	200	1000
Ethyl Acetate	5620	22,627	400	200

Table 1 shows the values of toxicity parameters of selected non-polar solvents. LD_{50} , LC_{50} , PEL, and OEL (permissible and occupational exposure limit values) were considered in this part. According to the above values hexane, heptanes, and ethyl acetate shows an effective toxicity level than other selected solvent and current industrial solvent. Therefore, these three solvents were used for further experiments in the research.

The swelling capability of each selected solvent was determined under the different maturation levels.

The swelling ability of each solvent was decreased with increasing the maturation levels. The cross-linking density is increased with maturation time, so the polymer chains become very short, and swelling decreases. This phenomenon is represented in Figures 3 and Figures 4. According to the graph, n-hexane and n-heptane solvents showed a similar swelling pattern to m-xylene (current solvent). The variation of the swelling pattern in both of the aliphatic hydrocarbons was similar. However, the swelling capability of xylene is not lower than other selected solvents. The main reasons for that

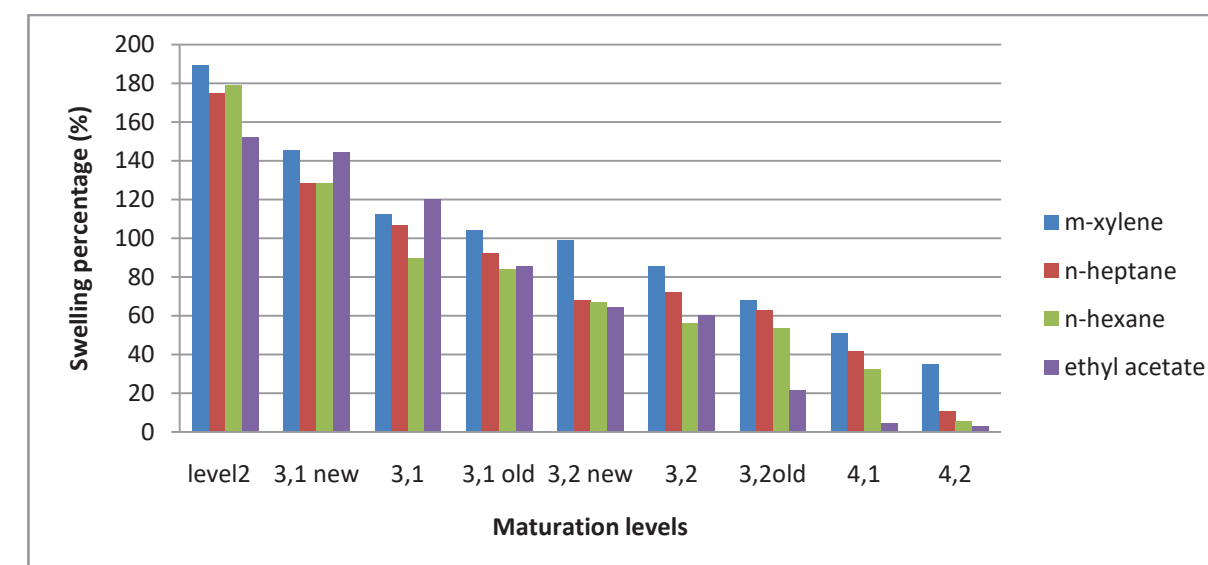


Figure 3: The swelling percentages of each solvent against the maturation levels of LC601

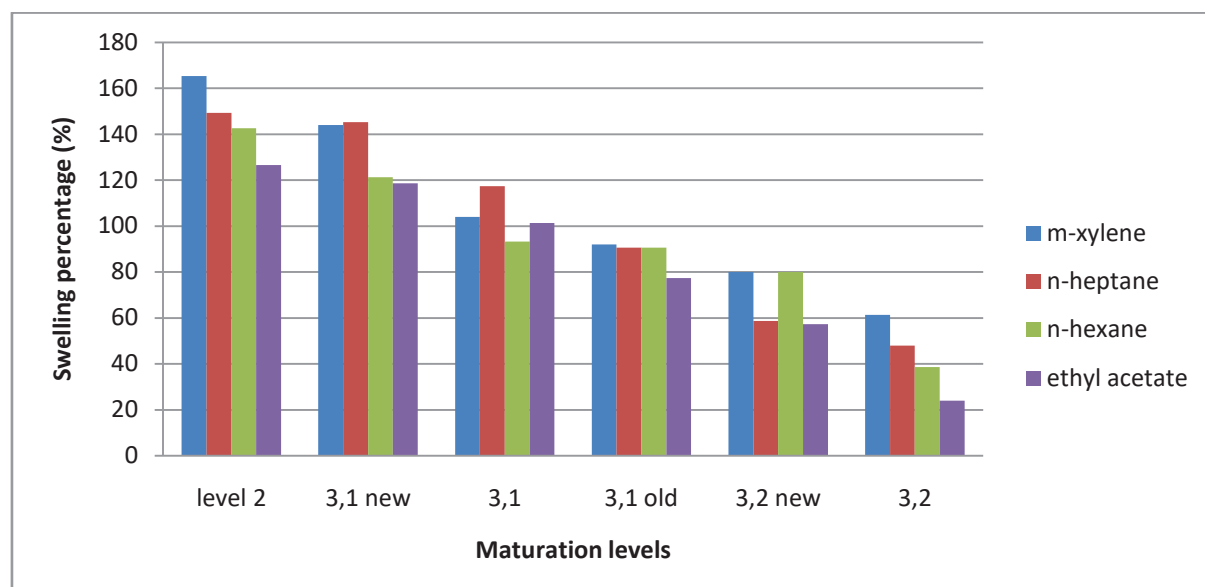


Figure 4: The swelling percentages of each solvent against the maturation levels of LC606

can be identified as the high non-polarity behavior and the compatibility of solubility parameters.

Conclusion

The main target of this study was to find an alternative organic solvent/solvent for xylene in the grip designing process of NR latex-coated glove manufacturing. The main reason for this investigation was the toxic nature of xylene and other aromatic solvents. After analyzing the toxicity of selected solvents and comparing it with xylene, three main organic solvents were identified for the laboratory experiments.

According to the swelling capability results, aliphatic hydrocarbons like n-hexane and n-heptane solvents showed positive results with the current solvent m-xylene. However, the swelling percentage variation results of aliphatic hydrocarbons have not exceeded the results of m-xylene. Finally, it can be concluded that the application of the aliphatic hydrocarbons (hexane and heptane) as an alternative for the grip designing step is effective to some extent level.

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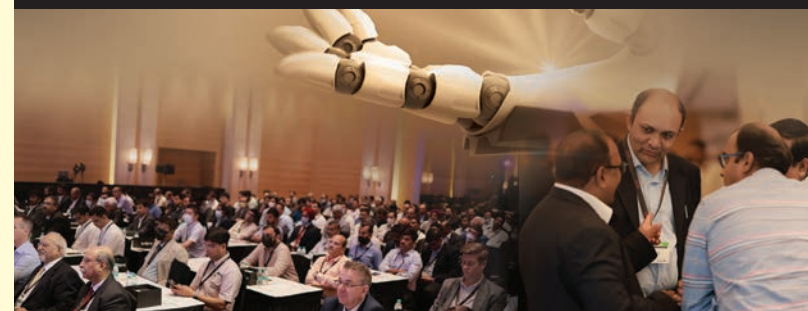
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Creativity is a Process that Anyone Can Learn

Fahad Farook

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In today's fast-paced world, the ability to think creatively and come up with innovative solutions is highly valued. From business to the arts, creativity has become a vital skill for success. However, many people believe that creativity is a gift, and that they are not creative because they find it difficult to generate new ideas. The truth is, creativity is not an inherent talent, but a process that anyone can learn.

The creative process involves several stages. The first stage is preparation, where the individual gathers information, researches, and examines the problem they need to solve. The second stage is incubation, where the brain processes this information subconsciously, allowing new connections to form. The third stage is illumination, where the "aha" moment occurs, and the individual comes up with a new idea or solution. The final stage is verification, where the idea is tested and refined to ensure its feasibility.

One of the biggest misconceptions about creativity is that it's a gift that only a few possess. However, research shows that everyone has the potential to be creative. The key is to understand that creativity is not just about

coming up with new ideas, but about the process of generating and refining them. By cultivating a growth mindset, anyone can develop their creative abilities.

Many people are held back by self-doubt and fear of failure. They are overly self-critical and judge their ideas harshly, which hinders their creative process. To overcome this, it's important to let go of perfectionism and embrace the process of trial and error. By accepting that not every idea will be successful and that mistakes are a natural part of the creative process, individuals can free themselves to take risks and generate more innovative ideas.

Another way to stimulate creativity is to expose oneself to diverse perspectives and ideas. By engaging with people from different backgrounds and cultures, individuals can gain new insights and perspectives that can inspire their creativity. Reading books, watching movies, and attending exhibitions are also great ways to expose oneself to new ideas and experiences.

This article will explore how creativity is a process that anyone can learn. By understanding the creative process,

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cultivating a growth mindset, and exposing oneself to diverse perspectives, individuals can unlock their creative potential and come up with innovative solutions to the challenges of today's world. With creativity, we can break away from the limitations of sameness and move towards a more exciting and dynamic future.

The Many Problems Surrounding 'Being Creative'

While creativity is a valuable skill that anyone can learn, there are several problems that individuals often encounter when trying to be more creative.

One of the most significant problems is assuming that great ideas will just "come to you" because that's how it seems to happen to other people. However, the reality is that coming up with innovative ideas requires effort and a deliberate creative process. The process of generating and refining ideas involves exploring different possibilities, experimenting with new approaches, and taking risks. Without putting in the effort to engage in this process, individuals will likely struggle to come up with truly innovative ideas.

Another problem that individuals face when trying to be more creative is self-inflicted pressure to come up with an idea quickly. The fear of not being able to come up with an idea can be paralyzing and prevent the brain from naturally connecting dots and traveling the creative path. This pressure can make it challenging to stay focused on the problem at hand and can hinder the creative process. By giving themselves time and space to explore different possibilities, individuals can reduce the pressure and allow their minds to work more freely.

Ignoring smaller ideas that you think aren't good enough is another problem that can prevent individuals from being creative. Creativity is a continuous and iterative process that involves building upon and refining ideas over time. Sometimes, what may seem like a small and insignificant idea can serve as the foundation for a more significant breakthrough later on. By dismissing these smaller ideas too quickly, individuals may miss out on the potential for creative breakthroughs.

For example, Leonardo da Vinci, one of history's most creative thinkers, was known for his extensive use of notebooks to record his ideas, observations, and experiments. His notebooks reveal that he often explored a variety of seemingly unrelated topics and allowed his mind to wander freely. He would also refine and improve upon his ideas over time, often revisiting them years later with new insights and perspectives. This approach allowed him to develop his many creative

innovations, including flying machines, robots, and anatomical drawings.

Another example of a highly creative thinker is Nikola Tesla, who was responsible for many of the technological advancements that we take for granted today. Tesla was known for his intense focus and ability to visualize his ideas in great detail before beginning to work on them. He also believed in the importance of collaboration and worked closely with other scientists and engineers to develop his ideas. By combining his visionary thinking with a disciplined approach to experimentation and collaboration, Tesla was able to develop groundbreaking innovations such as the alternating current (AC) electrical system and wireless communication.

So what are some ‘Thinking Processes’ you can use?

1. Divergent versus Convergent Thinking:

Divergent thinking refers to generating multiple ideas or solutions to a problem or question. This technique is useful in the brainstorming or idea generation phase of a project. Divergent thinking encourages individuals to come up with as many solutions as possible, without judgment or evaluation. For example, a team at a marketing agency might brainstorm a variety of possible ad campaign ideas for a new product launch.

Convergent thinking, on the other hand, is the process of evaluating and selecting the most promising solution from a list generated through divergent thinking. This technique is useful in the decisionmaking or problem-solving phase of a project. Convergent thinking involves analyzing the various solutions generated through divergent thinking and selecting the best one based on specific criteria. For example, after brainstorming ad campaign ideas, the marketing team might evaluate each idea based on factors such as target audience, budget, and timeline, and then select the most effective idea to move forward with.

2. Thinking about the problem versus thinking about the solution:

When trying to solve a problem, it is important to first understand the problem and break it down into smaller segments. This allows for a wider range of solutions to be generated in greater detail.

One way to do this is to use a technique called "chunking", which involves breaking the problem down into smaller, more manageable pieces. For example, if a company is experiencing a decline in sales, they might

break down the problem into smaller segments, such as targeting a new demographic, changing the pricing strategy, or improving the quality of the product.

By thinking about the problem in this way, a wider range of solutions can be generated. It also allows for a more detailed evaluation of each potential solution. Once the potential solutions have been evaluated, it is then easier to select the best solution to move forward with.

3. Giving your mind time to wander:

Scientific research has shown that our brains need time and space to subconsciously make connections and generate novel ideas. This is why taking breaks and giving your mind time to rest and wander can be important for creativity.

For example, many people have experienced coming up with great ideas while in the shower or going for a walk. This is because when we give our minds time to wander, we activate the default mode network in our brain, which allows for creative thinking and making connections.

It is important to note that this technique does not necessarily mean doing nothing. It can involve engaging in an activity that doesn't require much conscious thought, such as taking a walk or doing household chores. This allows your mind to wander and make connections subconsciously, which can lead to creative insights.

4. Thinking of other concepts or principles from unrelated fields and trying to apply them to your field:

This technique involves looking for inspiration from fields outside of your own and applying those principles to your own work. For example, Steve Jobs was inspired by a calligraphy class he took in college and applied those principles to the design of the first Macintosh computer.

This technique can lead to innovative and unique solutions, as it allows you to think outside of your own field and consider different perspectives. It can also be a useful technique for overcoming creative blocks, as it can spark new ideas and approaches.

In summary, these creative thinking methods can be powerful tools for generating unique and innovative ideas. By using techniques such as divergent and convergent thinking, breaking down problems into smaller segments, giving your mind time to wander, and looking for inspiration from outside fields, individuals

and teams can approach problems with a fresh perspective and generate more creative solutions.

Overcoming the Fear of Failure

One of the biggest obstacles to creativity and innovation is the fear of failure. People are often hesitant to take risks or pursue new ideas because they are afraid of making mistakes or being judged harshly. However, it is important to recognize that failure is a natural part of the creative process and can actually lead to greater success in the long run.

For example, in the tech industry, many companies practice a process known as "iterative design," which involves building prototypes and testing them with users in order to quickly identify flaws and improve the product. Google is a great example of a company that embraces this approach. While they are known for their many successful products and services (like Google Search, Gmail, and Google Maps), they have also had their fair share of failures, such as Google Glass and Google Wave. Google Wave was a collaborative platform launched in 2009 that aimed to merge email, instant messaging, and social networking into one interface. However, it was discontinued in 2012 due to low adoption rates. Similarly, Google Glass was a wearable device launched in 2013 that aimed to revolutionize the way we interact with technology. Despite early hype, it failed to catch on and was discontinued in 2015. However, both of these projects provided valuable lessons for Google that informed the development of more successful products, such as Google Docs and Google Home.

Elon Musk is another example of a successful entrepreneur who is not afraid of failure. Musk is known for taking on seemingly impossible challenges, such as revolutionizing the space industry with SpaceX and building a sustainable energy future with Tesla. He has also faced setbacks and failures along the way, such as the explosion of a SpaceX rocket during a test flight in 2016 and the production challenges faced by Tesla's Model 3. However, Musk has been able to learn from these experiences and continue to push forward with his ambitious goals.

While it's true that the cost of failure in terms of time and money can be high in the modern workplace, it's important to remember that failure is often a necessary part of the creative process. In fact, some of the most successful companies and individuals have embraced the concept of "failing fast" in order to learn and iterate quickly.

While the cost of failure may be high in some industries, it's important to remember that the cost of not innovating can be even higher. By creating space for failure and embracing it as a necessary part of the creative process, we can unlock our full creative potential and achieve greater success in the long run.

The key takeaway is that failure should not be feared or avoided, but rather embraced as a necessary part of the creative process. By taking risks and learning from mistakes, we can ultimately achieve greater success and innovation.

In Conclusion what would this look like for your daily life?

1. Try to focus more on the process than the output: This means valuing the process of generating ideas, rather than just the end result. It's important to give yourself time to explore different options and try out new things, even if they don't immediately lead to a successful outcome. This approach can be particularly useful when working on creative projects where there may not be a clear "right" answer. Instead, focus on the journey and enjoy the process of discovery.

2. Try to be less self-critical of the ideas you come up with: Self-criticism can be a major roadblock to creativity. When we are overly critical of our own ideas, we tend to shut down the creative process before it even has a chance to get started. Instead of judging your ideas too harshly, try to adopt a more curious and open-minded approach. Be willing to explore new possibilities and embrace the unexpected.

3. If you are a manager/leader/teacher or parent, try not to shut down ideas early on: This is particularly important in a team setting, where you want to create an environment that encourages creative thinking and collaboration. When someone brings up an idea, try to be open-minded and encourage others to build on it. Even if the idea isn't immediately feasible or practical, it

may spark a new and innovative approach that leads to success in the long run.

4. Give your brain time: It's important to give yourself and others time to think and process information before jumping to conclusions. This is especially true in situations where you need to come up with creative solutions to complex problems. Rather than trying to force a solution, take a break and allow your brain time to process the information and make new connections. This might involve stepping away from the problem for a little while or coming back to it later with fresh eyes. For an example at a team meeting don't expect ideas as immediately as you identify problems, maybe pick it up again at the end of the day when team members minds have had time to work out the problem from different angles.

5. Never be afraid to share something you think is 'stupid': Sometimes, the most seemingly insignificant ideas can lead to major breakthroughs. By sharing your ideas, even the ones you think are silly or trivial, you are opening up the possibility for new connections and insights. This is why it's important to create a safe and supportive environment where everyone feels comfortable sharing their thoughts and ideas, no matter how unconventional they may be.

By implementing these strategies in your daily life, you can become more open-minded, flexible, and creative in your thinking. You can learn to embrace failure as a natural part of the process, rather than fearing it, and be more willing to take risks and try new things. By encouraging creative thinking in yourself and others, you can foster a more innovative and collaborative work or personal environment.

Remember, creativity is not something that comes naturally to everyone, but it can be learned and developed with practice. So, don't be afraid to experiment, explore, and have fun with the creative process!

Polypropylene Random Copolymer (PPR) for hot water applications

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Abstract

A breakthrough in water distribution was the invention of thermoplastic pipes to replace Galvanized iron pipes (GI pipes). Polyvinyl Chloride (PVC) pipes play a major role among the other pipes due to their flexibility, durability, safety, and low cost compared to steel pipes. Despite being a part of everyday life, PVC has the drawback of not being able to withstand higher temperatures . Polypropylene random copolymer (PPR) becomes a solution to the aforementioned issue and also offers additional benefits to the pipe industry such as safety and chemical resistance, low cost, durability, and efficiency. PPR pipes, which have emerged as the preferred option for high-temperature pipe applications, are discussed in this article. Furthermore, the advantages and disadvantages of PVC pipes are covered in this article.

Key words: Polypropylene Random Copolymer, PPR, Hot water, PVC, Polyvinyl Chloride, high temperature

1. Introduction

The invention of thermoplastic pipes to replace the traditional galvanized steel pipes is a revolution in water transportation and distribution. As metal pipes come into contact with static water, it leads to corrosion while giving a metallic flavor to the water. Thus, it leads to health issues, and people tend to find replacements for GI pipes. As a result, the invention of thermoplastic pipes led to rapid public acceptance.

Among generally used thermoplastic materials, polyvinyl chloride (PVC) plays a major role in water pipes. PVC pipes are non-corrosive and light weight. They prevent the growth of bacteria, fungi, algae, and other biological toxins. But Unplasticized PVC is not very flexible, which makes it unsuitable for plumbing networks that need bends and joints. Therefore, plasticized PVC which is more flexible than unplasticized PVC became more popular, replacing the galvanized steel pipes. Despite the above-mentioned benefits, PVC pipes have the disadvantage of not been able to withstand higher temperatures.

Typically, hot water systems have boilers that carry hot water at about 60°C–83°C to various parts of the building via pipes. [1] As the softening point of PVC starts at about 70°C, it is not advisable to use PVC pipes for hot water distribution. [2]With the temperature fluctuations, PVC pipes tend to show some signs of damage in their properties like stiffness, pipe dimensions, pressure ratings, etc.

Therefore, PVC pipes are more suitable to be used in cold water systems and drainage systems for residential and industrial water systems.

2. Effects of temperature on PVC pipes

2.1 Structure

Compared to GI pipes, PVC pipes are flexible and can yield without fracturing under a load. They can comfortably deflect

excess material without putting any strain on the overall structure of the pipe. The PVC pipes can become stiffer with decreasing temperatures and more flexible with increasing temperatures. [3] The research has found that PVC joints lose 80% of their stiffness with an increase in temperature from 23–90%, destroying their natural flexibility. [4] This dramatic loss of rigidity causes a loss of structure and leads the plumbing system to disconnect from the rest.

2.2 Leakages

Like all other materials, PVC which has a thermal expansion coefficient of 3.0 x 10-5 in/in/°F can expands with temperature and contracts with a decreasing temperature. [5] As the PVC pipes have a high length-to-diameter ratio, the change in length is noticeable with temperature fluctuations. The change in pipe dimensions hinders the compatibility, flow rate, pressure rating, and structural integrity of the piping system. Thus, the dimensional changes hinder the tight seal between the pipe fittings that prevents leakage.

2.3 Pressure capacity

The pressure capacity of PVC pipes significantly depends on their operating temperature. As the operating temperature falls, the pressure capacity of the PVC pipe

increases to a level higher than its pressure rating. Despite the fact that the pressure capacity rises as the temperature falls, PVC displays brittle behaviors at low temperatures, leading to low energy brittle failures because of a significant drop in impact resistance. This brittle behavior can result in catastrophic failure. [6]Conversely, with the increase in operating temperature, the pressure capacity of the PVC pipes decreases to a level below its pressure rating.[3]Therefore, PVC pipes are not recommended for low temperature applications and are only recommended for temperatures up to 60°C [7].

Therefore, to address the above problem of inability to use in hot and cold applications, the researchers have found PPR (Polypropylene Random Co-polymer) [8].

3 PPR pipes

Polypropylene random copolymers are thermoplastic resins created by polymerizing propylene with ethylene or butene linkages added to the polymer chain. It is made up of chains of hydrocarbons in such a simple chemistry that allows it to have properties of being tough and long lasting.

During the production process, polypropylene is made flexible by using short chains and stiff by using long chains. Since both long and short chains are used during the manufacturing of PPR, it has both rigid and flexible properties. Because of PPR's flexibility, it helps to protect pipes from external damages such as impact and freezing. Further, it can absorb the stresses, including expansion stresses that can damage other systems. The stiffness shown by PPR helps to improve the system's performance and appearance. [9]

3.1 Properties of PPR

PPR pipes show unique properties that set them apart from other pipe materials. Heat resistance, thermal conductivity, smooth inner surfaces and chemical resistance are some of the properties.

3.1.1 Heat resistance

The PVC is recommended for use at no more than 60 or 65 °C. (With a maximum of 80 °C.) [10] This is because having a low softening point (the temperature at which an amorphous polymer starts to soften) of

approximately 70°C makes it unsuitable for high-temperature applications. [11] But the PPR, which has a softening point of 131.5 °C, has better heat resistance compared to the PVC. [12]Therefore, PPR is more suitable for hot water distribution pipes compared to PVC.

3.1.2 Low thermal conductivity

Traditionally, galvanized pipes are used for hot water distribution. But they have a high thermal conductivity of 52.0 W/mK compared to other plastic pipes. Heat transfer from the environment to the liquid inside the pipe or vice versa is higher with metal pipes compared to plastic pipes. Therefore, a high heat loss or gain occurs during the transfer of hot and cold fluids. Thus, it is advisable to insulate the pipes. But this adds an additional cost for installation of pipes. But PPR pipes, which have a low thermal conductivity of 0.15 W/mK compared to GI pipes, are a solution to the above problem as they can provide high efficiency at a low cost. [13, 8]

3.1.3 Chemical resistance

PPR has better chemical resistance compared to PVC because of its molecular structure. It shows excellent resistance to diluted and concentrated acids, alcohols, and bases and good resistance to aldehydes, esters, aliphatic hydrocarbons, and ketones. [14] In contrast, PVC has a lower chemical resistance because its molecular structure contains chlorine atoms, which can react with certain chemicals and reduce its resistance to chemical attacks. Therefore, though PVC is resistant to many alcohols, fats, oils, aromatic free petrol, and most corroding agents, including inorganic acids, alkalis, and salts, it should not be used with esters, ketones, ethers, or aromatic or chlorinated hydrocarbons as it will lead to swelling and a reduction in tensile strength. [15] Therefore, PPR is better than PVC in chemical resistance. PPR also exhibits better UV resistance compared to PVC. [16]

3.1.4 Non-Toxicity

The random incorporation of ethene units (up to 6% by mass) into polypropylene copolymers increases the flexibility of the polymer chain. Compared to PPR, PVC is a rigid material. Therefore, it must be plasticized to achieve flexibility. Generally, these plasticizers are low in molecular weight. Therefore, they can leach out from the pipe resulting in mechanical degradation and eventual contamination of the surrounding environment. This phenomenon can lead to contamination of drinking water [17, 18]. But as PPR is flexible, the addition of plasticizers is not necessary. Therefore, PPR is known to be safe for the human body as well as the environment. Thus, PPR pipes are suitable to carry purified water since they do not cause any pollution. [8]

3.1.5 Smoother inner surfaces

The PPR pipes have a very smooth inner wall compared to the PVC pipes. Therefore, they are less affected

by frictional resistance and pressure loss during the transportation and distribution of the fluids. Thus, contributing to the energy efficiency of the PPR piping system. [19] Further, PPR pipes are less damaged or cracked compared to PVC and metal pipes. Thus, it has better durability than other piping systems. [14]

3.1.6 Recyclable

PPR pipe can be recycled after being used for a certain time and it has a long life of at least 50 years.

3.2 Installation of PPR pipes

Heat fusion is commonly used to join PPR pipes and pipe fittings. During connecting,

the PPR pipes and fitting ends are simultaneously heated to critical melting points. The pipes are then immediately put in a straight line into the PPR pipe fittings and allowed to cool. Such welded pipes have a high success rate and strong contact performance. [20]

Because of the above properties, PPR pipes are now playing a major role in cold and hot portable water transportation and distribution in industries, residences, and public installations. They are also used to transport beverages, sanitary liquids, assertive chemicals, pressurized air, and highly acidic or alkaline solutions. [21]

4 Conclusion

With the development of plastics, metal pipes were replaced with PVC pipes. They were widely used by people because of their properties like flexibility, durability, safety, and low cost compared to steel pipes. Despite being a part of everyday life, PVC has the drawback of notwithstanding higher temperatures. Polypropylene random copolymer (PPR) becomes a solution to the aforementioned issue because of its higher softening point(131.5°C) compared to PVC (70°c). Further PPR pipes offer additional benefits to the pipe industry like safety, chemical resistance, low cost, durability, and efficiency.

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Evaluation of Suitability of Lemongrass Powder as an Alternative Antioxidant for Dry Rubber Composites

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Abstract

Ageing of natural rubber based products leads to reduction in various properties and hence deterioration in quality of the final products. The use of antioxidants (AOs) in rubber based compounding has been introduced to mitigate this issue up to a certain level. The commercially available AOs tend to generate hazardous substances which can affect the eco systems adversely. This study was carried out to probe the possibility of using lemongrass (*Cymbopogon citratus*) root stem and leaf powder (LGP) as an alternative natural AO for natural rubber based dry rubber composites. Cure and ageing properties of composites containing commercially available AOs such as N-isopropyl-N'-phenyl-p-phenylenediamine (IPPD), 2,2,4-trimethyl-1,2-dihydroquinoline (TMQ) and 2-2'-methylenebis [6- (1-methylcyclohexyl)-P-cresol] (WSP) were compared with those of the composite produced with LGP. The dry rubber composite produced without any AO was used as the control. The comparison revealed that the LGP incorporated composite generates better processing safety than that prepared with IPPD and higher cure rate index than that prepared with TMQ, which are considered as ubiquitous AOs in the industry. Additionally, the former composite provided superior qualities not only with respect to cure characteristics, but also in regard to retention of tensile strength and elongation at break than the WSP incorporated composite. It can be concluded that it is possible to substitute the phenolic type AO WSP with LGP in dry rubber composites.

Keywords: Lemongrass, antioxidants, cure characteristics, tensile properties, thermal ageing

1. Introduction

Antioxidants (AOs) play a vital role in retarding the undesirable reactions taking place between the organic matters with atmospheric oxygen. The aforementioned reactions can cause degradation of the properties of a rubber product which will eventually affect the quality of the product adversely. Addition of AOs to polymers depends on the chemical composition of the base material and the extent of exposure to the atmosphere. Generally, for most unsaturated polymers such as natural rubber 0.5-2 phr of AOs are added during the process (Thomas *et al.*, 2000). The categorization of AOs can vary according to its main functional groups, staining/non-staining nature and according to different test methods.

The main three classes of AOs used for this study falls into the paraphenylene diamines (PPDs), trimethyl-dihydroquinolines (TMQs) and phenolics (e.g. WSP) which are commonly used in the industry for rubber based applications. PPDs are known as the most powerful AOs which exert a high level of staining effect and scorching on rubber compounds. TMQs on the other hand exhibits a lesser staining effect than the PPDs and provide more or less similar AO activity to the rubber product. However, phenolic type AOs which are generally known as non-staining AOs have lower activity in comparison to PPDs.

The use of commercially available synthetic AOs cause numerous undesirable effects, short term and long term adverse health effects on human beings as well as disturbs the ecosystem equilibrium, e.g. 6PPD affects embryonic development of zebrafish (Xu *et al.*, 2022). As a result several studies based on natural AOs have been conducted during the past to probe the possibility of substituting commercially available AOs with natural sources (Zhao *et al.*, 2022, Sukatta *et al.*, 2021, Öncel *et al.*, 2019). This study was based on a novel approach where the suitability of lemon grass powder (LGP) was accessed in the areas of cure characteristics and physico-mechanical properties with the incorporation into rubber compounds. The phenolic substances present within the LGP plays the major role in the action of AO property (Soliman *et al.*, 2017).

2. Materials and Methods

Materials

The crepe rubber (1X) used for this study was supplied by the Rubber Research Institute of Sri Lanka, Dartonfield, Agalawatta and the other ingredients were sourced from the local market. The control natural rubber (NR) composite was prepared without any AO whereas in the other composites IPPD, TMQ, WSP and LGP were used.

Methodology

Mixing of the ingredients in the formulation given in Table 1 to produce the five NR composites was conducted using a laboratory scale two-roll mill.

Table 1. Formulation of NR composites

Ingredient	Function	Parts per hundred parts of rubber (phr)
Crepe rubber (1X)	Rubber	100
ZnO	Activator	5
Stearic acid	Co-activator	2
TMTD	Secondary accelerator	0.3
TBBS	Primary accelerator	1.5
CaCO ₃	Filler	40
White oil	Paraffinic Processing oil	4
Sulphur	Vulcanizing agent	2.5
WSP/TMQ/IPPD/LGP	Antioxidant	1

3. Results & Discussion

Cure characteristics

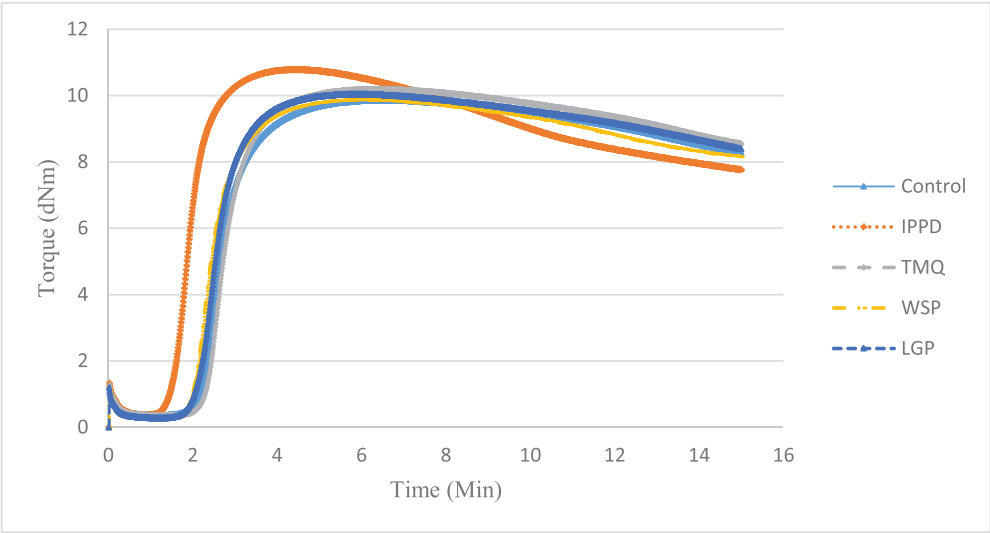


Figure 1. Rheographs of the NR composites

Analysis of cure characteristics

The cure characteristics of the composites, minimum torque (M_L), maximum torque (M_H), scorch time, 90% cure time and delta cure ($M_H - M_L$) were evaluated using a Rubber Process Analyzer (D-RPA 3000) according to ASTM D6601 at 150 °C.

The cure rate index (CRI) was calculated according to the following formula

$$CRI = \frac{100}{\text{Cure time} - \text{Scorch time}}$$

Preparation of test specimens

Test specimens required to carry out tensile properties before and after ageing were prepared using a hydraulic hot press according to the respective cure times obtained from the D-RPA.

Analysis of tensile properties

The Instron tensile testing machine was used to measure the tensile properties namely, tensile strength and elongation at break of the vulcanisates at room temperature (27 ± 2 °C) at a grip separation rate of 500 mm /min. in accordance with ISO 37: 2017

Analysis of resistance to thermal ageing

The rubber vulcanisates were aged at 70 ± 2 °C for 72 hrs in an air circulating oven at 100 °C (Sanyo Gallenkamp, UK) according to ISO 188: 2011. Tensile strength and elongation at break were evaluated after ageing.

The cure curves of all the composites are illustrated in Figure 1. According to the curves it can be seen that the composite with LGP indicates similar characteristics to

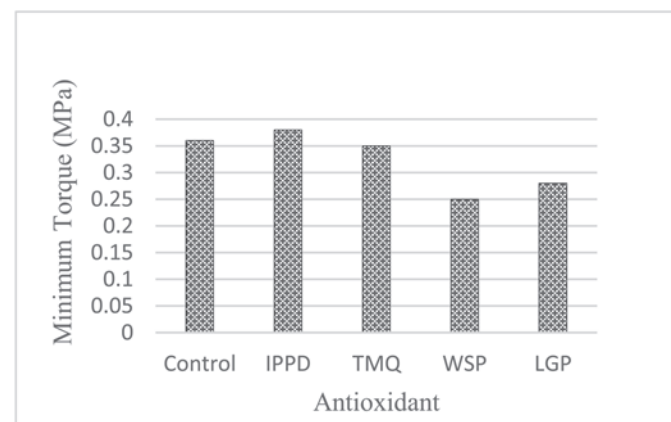


Figure 2. Minimum torque of the NR composites

The minimum torque which indicates the stock viscosity and processability of the unvulcanized rubber composite shows greater values for the control composite and the ones with staining AOs (IPPD and TMQ) and lower values for WSP and LGP incorporated composites (Figure 2). The LGP incorporated composite shows lower viscosity and enhanced processability in comparison to the composites containing IPPD and TMQ. The highest maximum torque can be observed in the compound with IPPD and the lowest being the composite with WSP (Figure 3). The maximum torque of the LGP containing composite is in between the TMQ containing composite and the WSP containing composite. This indicates that the LGP containing composite provide better results

those of the composites containing TMQ and WSP as well as to those of the control.

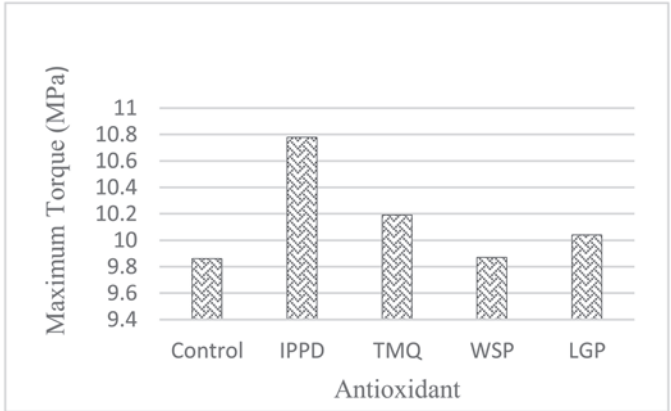


Figure 3. Maximum torque of the NR composites

than the WSP containing composite in regard to the maximum torque enabling a reasonable level of hardness for the vulcanizate.

Further, the LGP incorporated composite reveals better scorch safety compared to that of IPPD and WSP incorporated composites (Figure 5). Figure 4 indicates that the composite prepared with IPPD cures faster than all the other composites and is in agreement with the results of cure rate (Figure 7). When considering the cure rate, the LGP incorporated composite exhibits the second highest value indicating a better efficiency of curing than the control, TMQ and WSP containing composites.

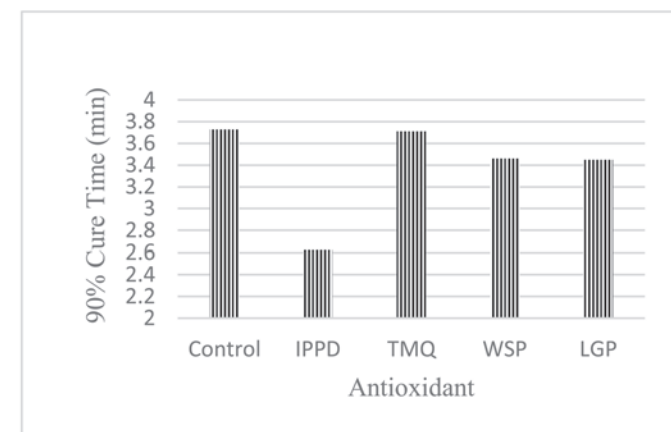


Figure 4. Cure time of the NR composites

Delta cure ($M_H - M_L$) of a rubber compound can be related to its crosslink density and hence the results illustrated in Figure 6 reveal that the LGP incorporated composite has a higher crosslink density than the WSP incorporated composite.

Overall, comparison of cure characteristics of all the five natural rubber composites indicates that the LGP incorporated composite has better characteristics than the WSP incorporated composite with respect to maximum torque, scorch time, delta cure and cure rate index.

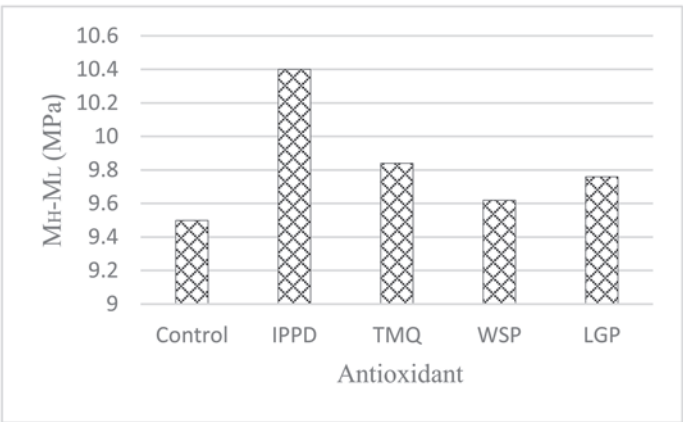


Figure 6. Delta cure of the NR composites

Tensile properties before and after ageing

Tensile strength of the five vulcanizates before ageing indicated almost similar values ranging from 21.2-21.4 MPa (Figure 8). However, with the applied ageing conditions the tensile strength has deteriorated giving the lowest value for the control (14.7 MPa) and the highest value for the TMQ incorporated composite (20.1 MPa). The ageing resistance of the LGP incorporated composite is higher than that of the composite prepared with WSP.

Elongation at break of the vulcanisates before and after ageing is illustrated in Figure 9. There is a variation in elongation at break among the vulcanisates before ageing. The highest and lowest values are shown by the TMQ and IPPD incorporated vulcanisates, respectively.

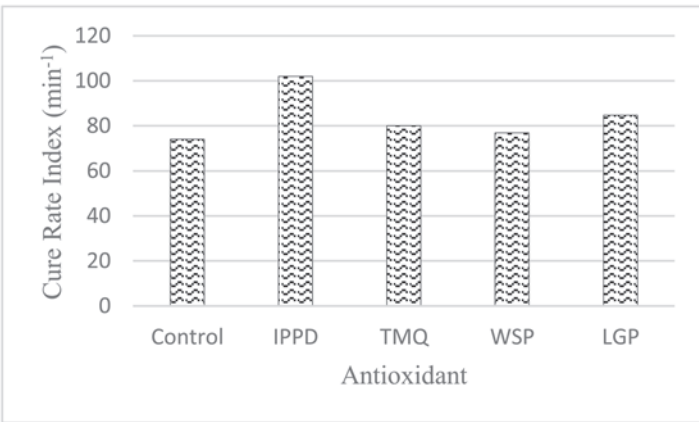


Figure 7. Cure Rate Index of the NR composites

However according to after ageing results, elongation at break of the three vulcanisates produced with TMQ, WSP and LGP is almost similar and the control exhibits the lowest value.

Retention of tensile strength and elongation at break after ageing for 72 hrs is illustrated in Figure 10. The retention values with respect to tensile strength indicate that the vulcanisates produced with the AOs TMQ and IPPD have greater resistance towards thermal ageing followed by LGP and WSP incorporated vulcanisates. The percentage retention values of elongation at break after ageing indicate similar results for TMQ, WSP and LGP incorporated vulcanisates, whilst the IPPD incorporated vulcanisate has generated a superior result (96.4 %).

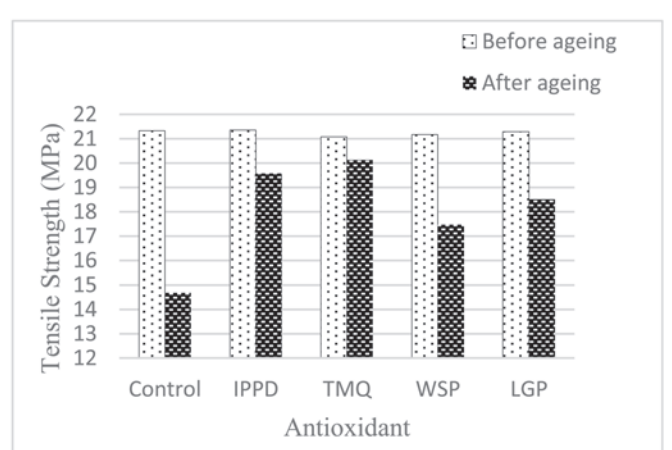


Figure 8. Tensile strength of the NR composites

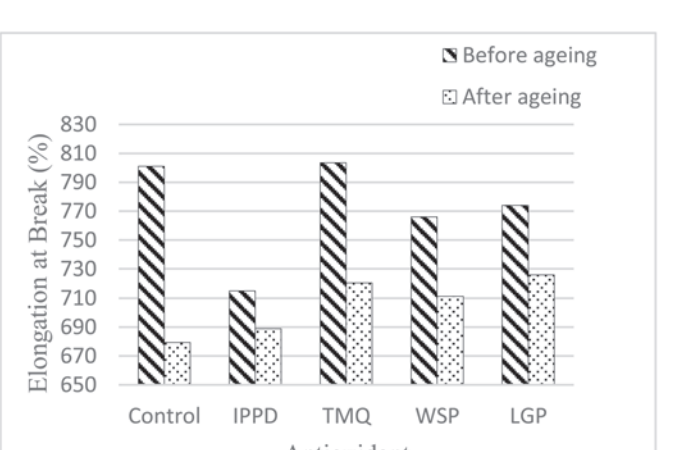


Figure 9. Elongation at break of the NR composites

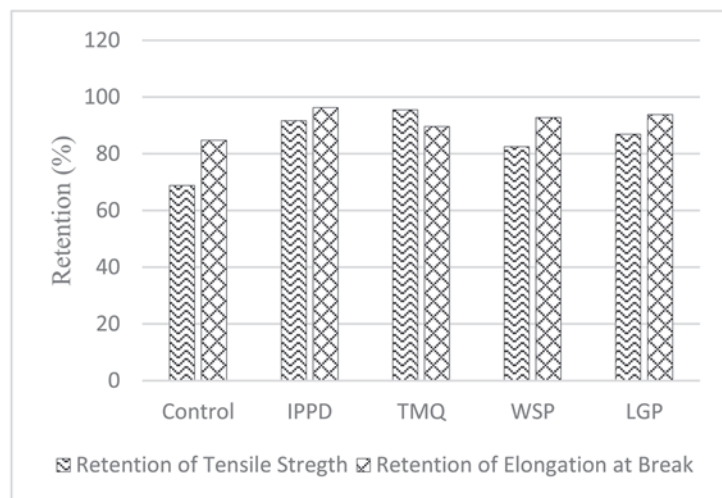


Figure 10. Percentage retention of Tensile strength and Elongation at break of the NR composites after ageing

4. Conclusion

The possibility of using LGP as an alternative AO in NR composites was evaluated in this study. The performance of the LGP incorporated composite was superior to that of the WSP incorporated composite in respect to the cure characteristics maximum torque, scorch time, delta cure and cure rate index. Additionally, the results of tensile strength and elongation at break of the former composite after ageing were higher than those of the latter composite. Further, the LGP incorporated vulcanisate generated favorable results than the control vulcanisate in regard to retention of tensile strength and elongation at break. Hence, it can be concluded from the results generated through the studies on cure characteristics, tensile properties and thermal ageing that LGP has the ability to be substituted as a potential AO for NR composites, especially as an alternative for phenolic AOs such as WSP.

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Active packaging systems for food applications

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The active food packaging is designed to prevent food degradation from microorganisms, and outside influences such as heat, light, humidity, and so on. The end user is also benefitted by having access to information about the ingredients and the nutritious values of the food package. Moreover, the consumer has the option to choose between the different sizes and shapes of packages for easier use.

The ever-increasing consumer demand and awareness of food quality and safety have contributed to emerging active and intelligent packaging technologies. The active packaging systems provide for enhanced food quality and shelf life while intelligent systems feedback additional

information on the quality during transportation and storage as well. The active and intelligent packaging system market is predicted to grow up in the near future.

Active packaging

Active packaging has several advantages over traditional packaging. Active packaging uses technology that deliberately releases or absorbs compounds from the food or the space of food packaging to increase the shelf life of products by preventing moisture loss, microbial growth, and lipid oxidation. The Table 1 below summarizes the most significant advanced active packaging systems in the current food industry.

Table 1 Active packaging systems in the market

Trade name	Manufacturer	Principle	Type
Zero2	Food Science Australia, Australia	Photosensitive dye	Oxygen scavenger
Bioka	Bioka Ltd., Finland	Enzyme based	Oxygen scavenger
Freshpax, Fresh pack, Freshmax	Multisorb Technologies, USA	Iron based	Oxygen scavenger
Freshilizer	Toppan Printing Co. Ltd, Japan	Iron based	Oxygen scavenger
Oxyguard	Toyo Seikan Kaisha Ltd, Japan	Iron based	Oxygen scavenger
Ageless	Mitsubishi Gas Chemical Co. Ltd, Japan	Iron based	Oxygen scavenger
Agion	Life Materials Technology Limited, USA	Silver based	Antimicrobial packaging
Biomaster	Addmaster Limited, USA	Silver based	Antimicrobial packaging
Tenderpac	SEALPAC, Germany	Dual compartment system	Moisture absorber
Dri- Loc	Sealed Air Corporation, USA	Absorbent pad	Moisture absorber
SANICO	Laboratories STANDA,	Antifungal coating	Interleavers
Evert- Fresh	Evert-Fresh Coporation, USA	Activated zeolites	Ethylene scavenger

Various methods such as moisture and temperature control, oxygen removal, and insertion of additives like salt, carbon dioxide (CO₂), sugar, conventional acids or a mixture of these items are implemented to improve the shelf life and maintain the standard of food packages

[1]. The progress of active packaging has further delayed oxidation in muscle foods, controlled respiration rate in horticultural products, moisture migration and microbial growth in dried products. Further, by means of active packaging, it is possible to control the atmospheric

accumulation of vaporous substances inside the package by lamination, co-extrusion, micro-perforation, coating

or polymer blending [2]. Some of the active agents that are used for food packaging is shown in Figure 1.

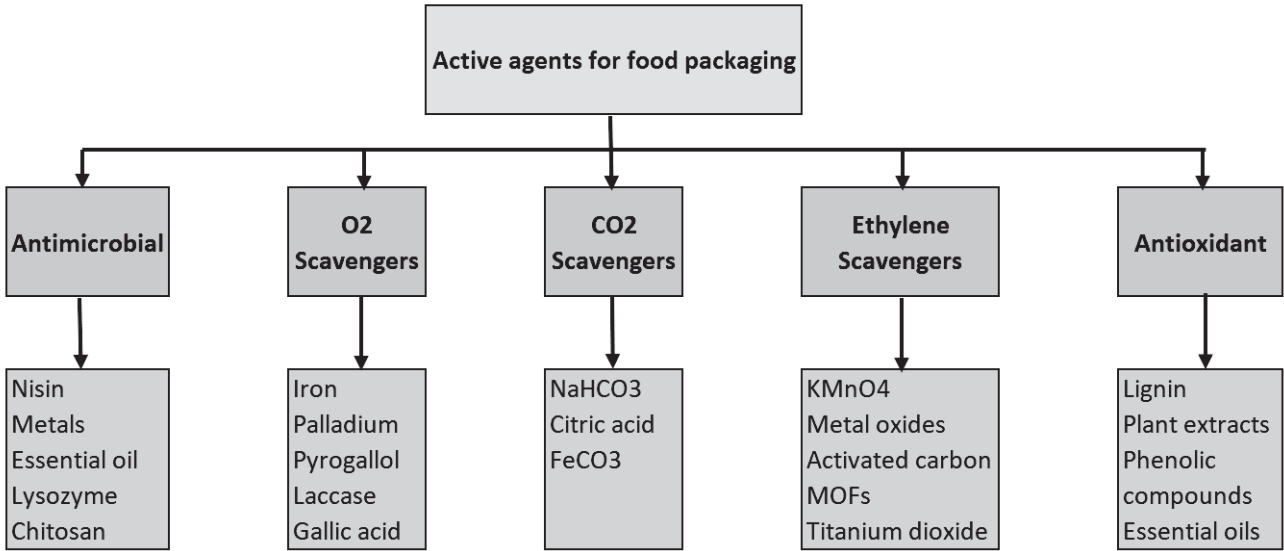


Figure 1 Active agents for food packaging systems

Antimicrobial packing

Antimicrobial packing is a system that kills or inhibits the growth of microorganisms. In this process, the growth of microorganisms present in the food or packing material is retarded or inhibited [3]. Antimicrobial materials can be added or overlaid onto food packaging medium to control the microorganism growth on food [4]. Natural antimicrobial essences can be derived from condiments like cinnamon, clove, rosemary and herbal plants like garlic, and onion. Pediocin, and nisin are few examples for natural food bio-preservatives produced by fungal and bacterial actions [5].

Antimicrobial package material is twofold. Some antimicrobial agents drift to the outer layer of the packaging medium while some antimicrobial agents are active without migrating to the outer layer of the packaging medium [6]. The application of antibacterial stuff directly on food surfaces is restricted as the active material is likely to offset during contact or spread from the outer layer to food [7]. Peptides, polyamines, enzymes and organic acids are some examples for antimicrobials with functional groups. Many polymers exhibiting antimicrobial properties like chitosan can be applied on vegetables and fruits to prevent damage caused by fungi [8]. Antimicrobial agents have been successfully incorporated to edible composite films and coatings based on polysaccharides or proteins such as starch, cellulose derivatives, chitosan, whey protein, and soy protein [9].

Oxygen scavengers

Oxygen scavengers are used widely in active packaging technology for foods today. Oxygen in a package speeds up the process of oxidative decaying of food and helps the growth of aerophilic microbes, off-flavor and smell development, colorant changes and nutrient losses and overall shelf-life security of muscle foods [10]. It is therefore necessary to control the presence of oxygen levels in food packages to restrict the rate of spoilage reactions in food. Even the use of modified atmosphere packaging (MAP) or vacuum packaging is not 100% successful for highly oxygen-sensitive foods as oxygen can permeate through the package cover in to the food package. Oxygen scavengers are employed to extract the residual oxygen after packaging and to keep the quality change of food to minimum due presence of oxygen [11]. On the other hand, the duty of oxygen absorbers is to bring down the oxygen level in the food package to less than 100 ppm. Nowadays, there are many systems of oxygen scavengers based on metallic and non-metallic compounds like iron powder oxidation, ascorbic acid oxidation, and photosensitive dye oxidation [12].

The oxygen scavengers can be mixed with MAP. Surprisingly less expensive oxygen scavengers are used to take away the residual oxygen in the MAP [13]. The structural shape of the oxygen scavenging aspect of a package can be a sachet, label, film, card or sheet. Cards and sheets can also be used in food packages to replace sachets [14] although the oxygen scavenger sachets with iron compounds have a higher capacity than the plastic films or sheets. Oxygen scavengers can be inserted into

the package to protect the foods in case of accidental rupture of sachets [15].

Carbon dioxide absorbers and emitters

The microbial increase on foods inclusive of fresh meat, fish, cheese, chicken and baked products can be mitigated by way of adding carbon dioxide to the packaging surroundings [16]. Soluble gas stabilization (SGS) technology is the first step for dissolving carbon dioxide (CO₂) into the product prior to packaging in order to prolong the shelf life [17] of these foods. It's far vital to flush the ingredients with an excessive percentage of CO₂ around 80%. In this manner, CO₂ can be absorbed by the meals growing a low vacuum [18], particularly at low temperatures [19]. Excess CO₂ can be filtered out by using CO₂ scavengers. A typical example of the application of CO₂ scavenger is roasted coffee packed in fully sealed packages. As CO₂ emission from coffee in a sealed package can be quite sufficient to burst the package [20], CO₂ scavengers are used to prevent the bursting of sealed coffee packages.

Moisture control

Excessive or insufficient moisture in a food package can cause fast deterioration of foods. Excessive moisture in food accelerates microbial growth [21] and changes the texture of foods. The dry powder nature of food like coffee powder or condiment powder can change to a sticky cake-like product [22] if the moisture content in the package is left uncontrolled. Therefore, the employment of a moisture regulator is a pertinent requirement to maintain the original dry nature of the food within limits. Condensation from vegetables and fruits can build up on production equipment as well supporting the risk of contamination by mold, mildew or microorganisms. A Common process involved in moisture absorption in food packaging is physisorption. During the transport of frozen fish [23] by air freight, large volumes of mats and carpets are used to absorb liquified ice. A drip-absorbent sheet includes a liquid-pervious upper layer sheet and a liquid-absorbent lower layer sheet bonded to the bottom surface of the upper layer sheet. Dehydrating agents like calcium oxide, silica gel are suited for meals like cheese, nuts and chips.

Antioxidant release

Oxidation causes deterioration of food and loss of nutritional values due to vitamin degradation. Antioxidants play a crucial role in prolonging the shelf life of food stuffs by enhancing the oxidation stability of foods. Beta-carotene, vitamins C and E, polyphenols are natural antioxidants. Coated films of Vitamin C, and E

have the ability to combat the putrid odour and colour changes in oily fishes. But, most of the antioxidants found in packaging materials are artificial. The most crucial synthetic antioxidants are in the group of gallates. Gallates are combined mostly with margarine and vegetable oils to prevent them from going rancid and preserve their taste. Two other antioxidants which are not found in the above groups are butylhydroxyanisol (BHA), and butylhydroxytoluene (BHT). BHA and BHT are generally used for sweets, processed cheese, instant soups and peanut butter [24].

Ethylene scavengers
Ethylene is a gas naturally found as a plant growth hormone. The presence of very low quantities of ethylene is effective in speeding up the process of fruit ripening. Ethylene is capable of shortening the shelf life of various fruits by speeding up fruit ripening and floral senescence[25],[26]. The prolonged exposure of vegetables and fruits to ethylene can affect the quality, taste, odour and colour. Ethylene scavengers are used to limit the ethylene buildup in food packages by prolonging the shelf life and keeping the original food quality. Potassium permanganate is the most widely and commercially available ethylene scavenger, it removes ethylene by oxidizing it into ethylene glycol followed by decomposition in carbon dioxide and water. Practical application is to use zeolite and transition metals in small sachets as Ethylene scavengers.

Challenges

Prospective quality and safety benefits [27] of antimicrobial packaging have gained the interest and attention of researchers in the industry. Naturally-derived antimicrobial agents, biodegradable solutions and bio-preservatives are the areas where future research has to be mainly concentrated and aimed in microbial active packaging. Bio-degradable packaging technology has already contributed to many innovations in the packaging field with improved food quality and safety showing the practicality of bio-active functional components. More importantly, the preservation of original mechanical and barrier properties [28] of food is also essential with further development of active materials as it leads to prolong shelf life and food security.

Food waste is also another concern as loss of food can happen at different stages in the food supply chain [29]. Further research is to be carried out to enhance packaging along the entire lifecycle keeping food waste to a minimum. A commonly found weakness in packing is improper and inadequate sealing of packages. For example; a grain spillage from a sack may attract pests like rodents that can spoil the grain and make it unsuitable for human use. Regulations are to be

imposed for the preservation of perishable foods during transportation and storage.

Opportunities

Nanotechnology is supposed to play a crucial role in food packaging in the future complying with safety concerns associated with packaging. Demand for appropriate and safe advanced packaging stuff is a key requirement according to Majid et al. [30]. These materials are intended to administer the liberation of active agents in combination with detectors implanted in the packaging system.

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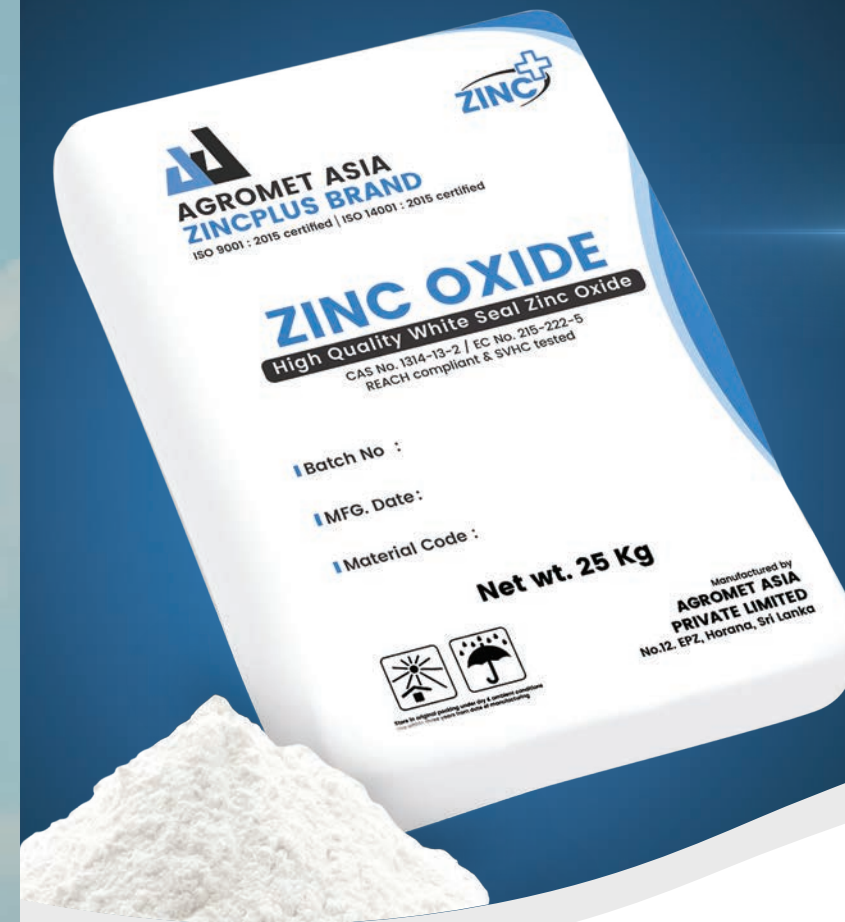
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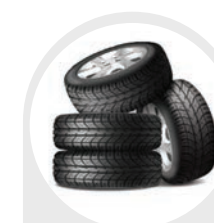
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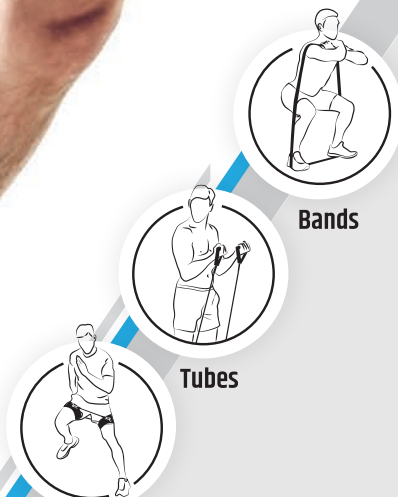
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“Sustainability - Circular & Green Economy

Challenges and Opportunities for Tyre & Rubber Industry”

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Abstract

Over the past decade, the concept of a “green economy” has moved into the mainstream of policy discourses across the world. A green economy takes care of human well-being, social equity and reducing environmental impacts. Therefore, transitioning to a green economy has sound economic and social justification. There is a strong case for governments as well as the private sector to engage in this economic transformation. For governments, this transition would involve levelling the playing field for greener products by replacing harmful subsidies, reforming policies, redirecting public investment etc. In private sector, this transition would involve responding to these policy reforms and incentives through increased financing and investment, skill building and innovation capacities to take advantage of opportunities arising from a green economy.

The general perception among the people at large about the manufacturing industry, in particular Tyre & Rubber industry is that they are not environmental friendly, energy inefficient, use non-renewable resources etc. To change this perception tyre & rubber industry has to work towards sustainability, circular & green economy through development of green technology, green manufacturing including Resource decoupling - using less land, water, energy & materials to maintain economic growth and to reduce environmental impact.

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Introduction

Economies today have two major challenges: The need to create a sustainable growth oriented economy, and the need to be competitive in the global market. It is well known that our current industrial society is on a path of "unsustainable" growth. The industrial revolution was an important step forward when the Earth housed only 1.0 billion people. But today, with more than 7.0 billion based on fossil fuels, unbridled consumption and throwaway products is just not sustainable. Further more, a "no growth" scenario is just not a realistic one when running a business or leading a country. If living standards of the people at the bottom of the pyramid (presently 5.0 billion) is to improve along side population growth (expected total world population 10 billion by 2050), it will be done at the cost of our mother planet with the present “unsustainable” growth approach dependant on crude based economic model. So, the solution must be "**sustainable**" growth through **Circular & Green Economy**.

In a future oriented approach, the United Nations (UN) as a neutral body with the set goal of balancing the needs of mankind, defined 17 sustainable Development Goals (SDGs) in September 2015. Based on the principle of “nobody left behind”, the UN agenda constitutes a holistic approach to achieving a sustainable future for all. The SDGs provides us with a frame work which should enable society to translate global needs and ambitions into solutions. Simultaneously, the agenda points out distinct **megatrends** for industry and society, which will also directly influence the rubber & tyre industry.

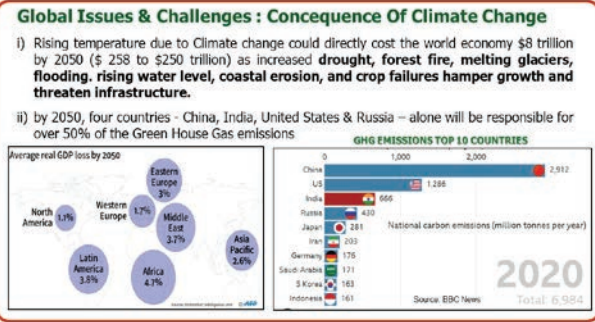
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Megatrends for Industry and Society:

- Urbanisation
- Growing (and aging population)
- Potable water
- New mobility (Connected, Autonomous, Shared & Electric)
- Digitization (Industry 4.0)
- Sustainability



UN’s Sustainable Development Goals (SDG)

- The Sustainable Development Goals (SDG) were adopted by all United Nations member states in September, 2015 as a universal call on the principle of “nobody left behind”
- This is holistic approach to achieving a sustainable future for all.
- SDGs provide framework which should enable society to translate global needs and ambitions into solutions.
- It also points out distinct megatrends for industry and society, which will also directly influence the rubber industry.
- Tyre Industry selected eight SDGs as priorities and where the sector can have the highest impacts :



Linear Economy & Green Economy

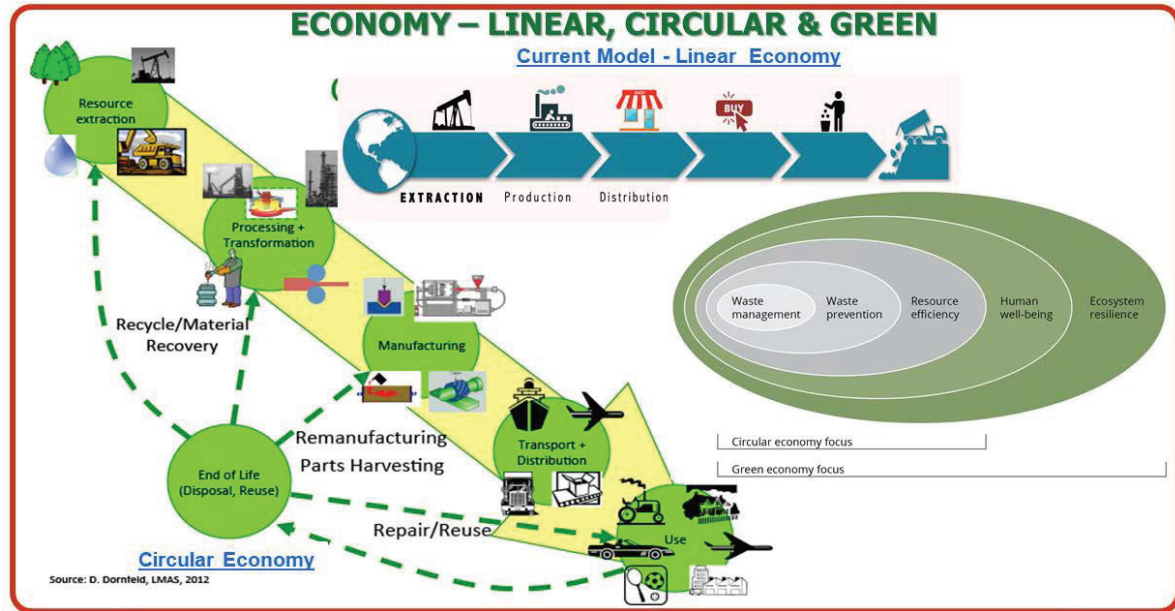
Linear Economy – Take, Make, Use and dispose model of production.

Shared Economy – It is a socio economic system built around sharing of resources. Eg. Free lancing platforms, co-work spare, peer to peer lending, fashion platform etc.

Circular Economy – It is a regenerative development strategy for economic growth that focus on restoration,

waste through superior design of materials, product, systems and business model.

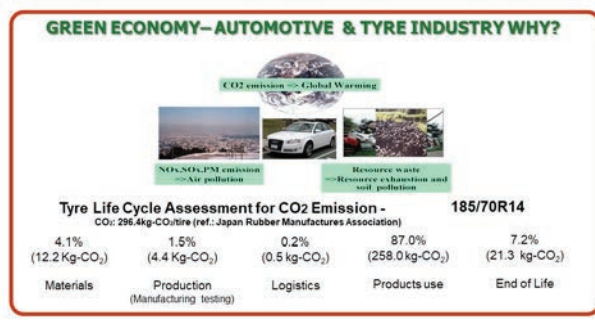
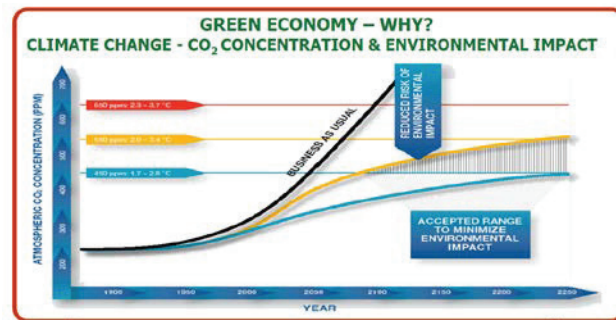
Green Economy –It is an interconnected economic activity that promote global scale sustainable development, poverty eradication, environmental protection and eco efficiency and low carbon development. It results in increased human well-being and social equality, while significantly reducing environmental risks and ecological scarcities.



Environmental Risks	Ecological Scarcities
Failure to Adapt to Climate Change	Less or no provision of ecosystem services which include:
Incurable Pollution	Food, Water,
Land and water mismanagement	Raw material,
Mismanaged Urbanisation	Genetic Resources (Pollination)
Rising Greenhouse Gas emissions etc.	Energy, Minerals, Medicinal resources etc.

Sustainability – Circular & Green Economy Why?

- Initiative born out of multiple crises and accelerating resource scarcity (limited resources – infinite demand).
- An economic vehicle for sustainable development
- Can take advantage of new growth trajectories designed to be more socially inclusive, as well as responsive to poverty reduction and economic diversification objectives
- A new economic paradigm that can drive growth of income and jobs, without creating environmental risks



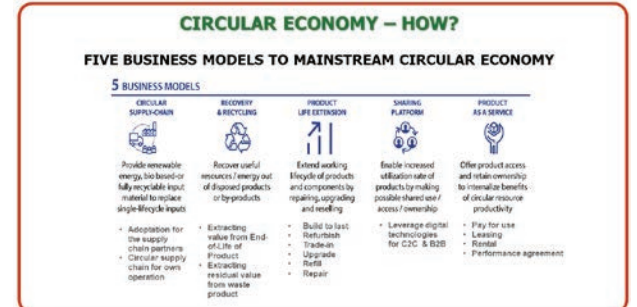
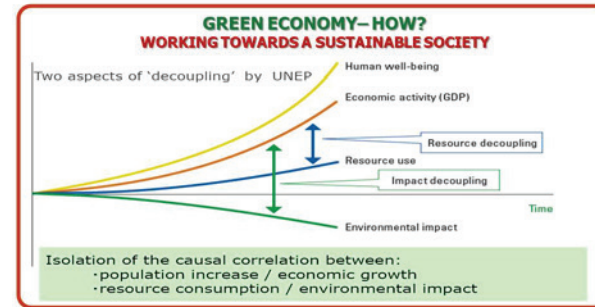
Sustainability – Circular & Green Economy How?

The remarkable economic and population growth of the 20th century was closely coupled to substantial increase in the extraction and consumption of natural resources, leading to increasingly damaging negative environmental impact. However, economic growth globally was faster

than the growth of rate of consumption of natural resources and some negative environment impact have been reduced. It appears that some dematerialisation of the world economy has occurred spontaneously. Accelerating the process of decoupling economic activity from consumption and environmental impact is fundamental to future human well-being. Transition

from present crude based economy to green economy is possible only through Decoupling of natural resources

used and environmental impact from economic growth.



Challenges – Circular Economy

- Achievability of the concept of the Circular Economy
- Desirability for businesses on circular economy objective
- Collection and centralization of the end-of-life products for processing in an economical fashion
- Use of 100% renewable energy as per circular economy objective in contradiction related to resource efficiency
- Addressing social dimension & sustainability as per the frame work of circular economy.
- Without disturbing existing economic activities, deployment of circular economy both at national and international level.

Opportunities of Sustainability – Circular & Green Economy

- Can reduce poverty and inequality. Inextricable link between poverty alleviation and wise management of natural resources and ecosystems
- Ecosystem services provide 47% to 90% of the so-called ‘GDP of the poor’
- Common interest between developed and developing countries
- Partnership of policymakers and business community
- Crucial to prioritize spending in sectors that can simultaneously promote social, economic and environmental gains



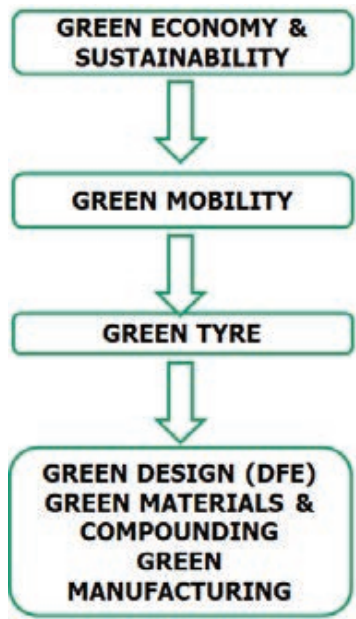
Circular & Green Economy – Drivers & Challenges for Tyre & Rubber Industry

Drivers:

- Sustainability & Green Mobility
- Legislations & Regulations (Tyre Labeling)

Challenges:

- Technology Innovation Challenge
- Real-time Simulation & Tyre Testing
- Multiscale Simulation Technology
- Material & Product Complexity Challenge
- Green Material/Manufacturing
- Smart Manufacturing - INDUSTRY 4.0
- Manufacturing Implementation Challenge
- Supply Chain Management

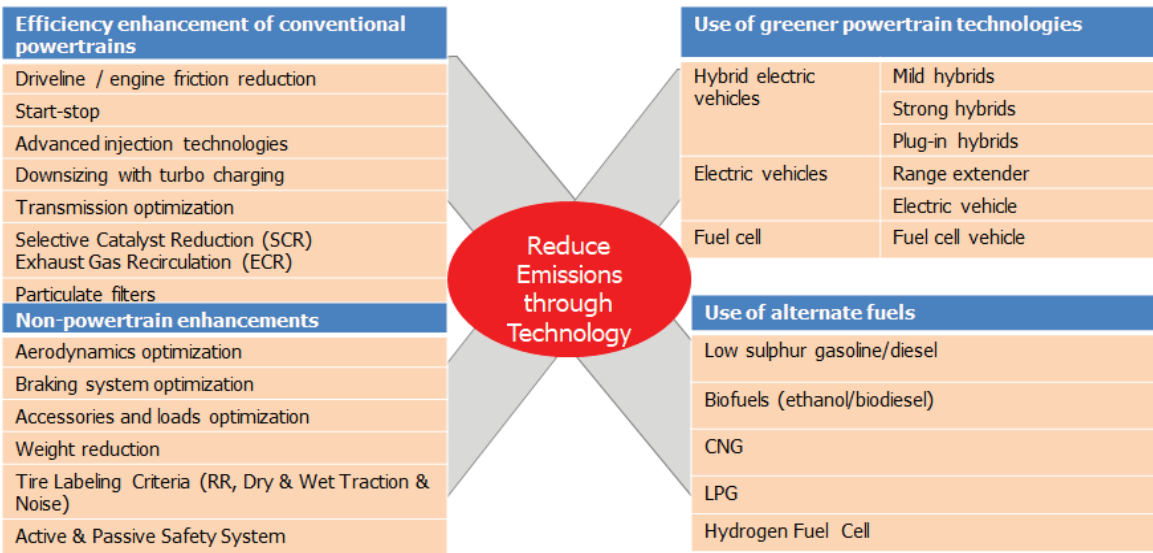


Sustainability – Green Mobility Approach

- **Technology Selection & Strategy :** Sustainable Technology works closely with organisations to select and implement the most appropriate vehicle technologies within the context of a long term technology strategy.
- **Low Emission Technologies:** Sustainable Transport advises on vehicle technologies that reduce CO₂ and air quality emissions from road transport including biogas, hybrid and plug-in electric vehicles

- **Carbon & Air Quality management:** Sustainable transport audits transport emissions and helps with identification and implementation of appropriate abatement technologies and behavioural change measures
- **Green Fleet management:** Sustainable Technology helps organisations measure and reduce the environmental impact of their fleet operations and employee business travel including grey fleet issues

Green Mobility – Technology Trends for Emission Reduction



Sustainability –Technology Innovation Challenges :

Mega Trends for Automobile & Tyre Industry

- Sustainable tyre and green material technology [further improvement in RR (Rolling Resistance), safety, durability and NVH (Noise, Vibration and Handling)].
- Rubber material from bio-mass
- Completely recyclable tyre, reversible cross linking system
- Greater use of modelling in performance prediction and tyre design
- Real time simulation & Tyre testing
- Application of sensor technology to development of intelligent tyres. In particular use for data collection

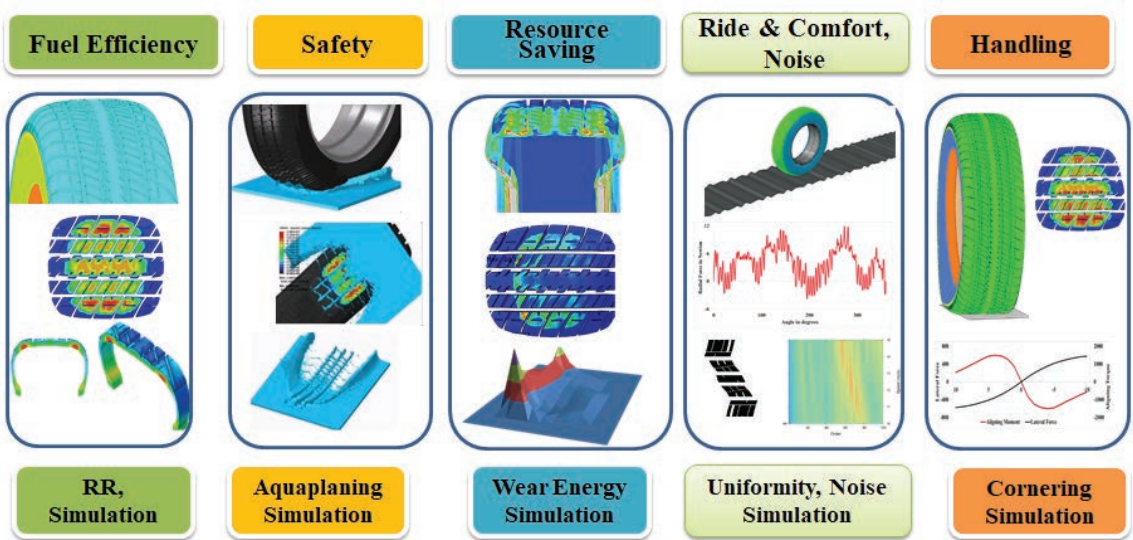
Sustainability - Role of Simulation in Tyre Development

Uses of Simulation & predictive technology, Finite Element Analysis (FEA), service life prediction etc. will improve in determining the reliability aspect of tyre. With the advent of high end software, FEA tools are now extensively used for prediction of structural durability,

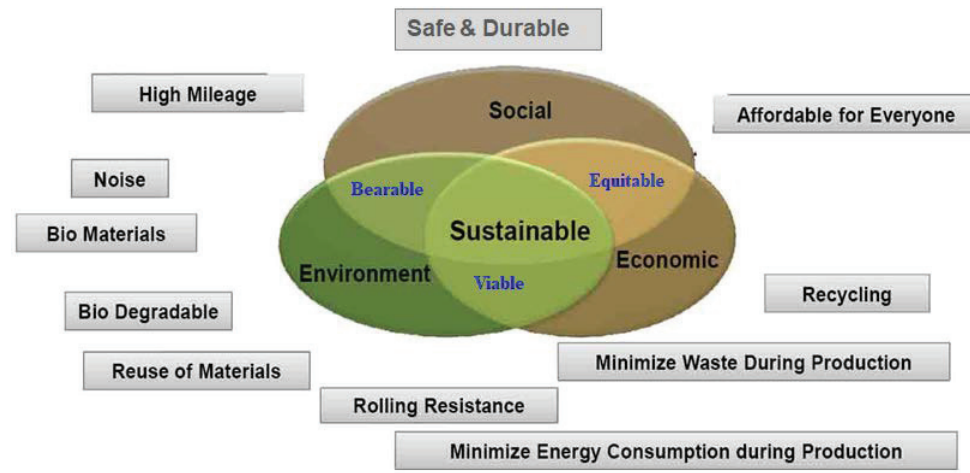
and logging to help with fleet maintenance

- Autonomous Electrical vehicle
- change in tyre design to tall and thin tires, especially to suit EV
- Temperature and Wear Rate for Autonomous Vehicles
- Electrified Rubber with real time monitoring and to respond to road conditions
- Weight reduction technology (tyre) to the extent of 50% by 2050 without sacrificing performance
- Virtual proven ground
- Self-Inflation Technology (SIT)
- Future tyre may generate Electricity
- Non Pneumatic tyre
- Smart Manufacturing (Industry 4.0)

aquaplaning, heat generation, process simulation and NVH. Advanced research is in progress to understand the microscopic behavior of polymer-filler interaction using new generation simulation techniques. This in turn will help to develop ultra high performance tyres with reduced hysteresis and improved safety and durability.



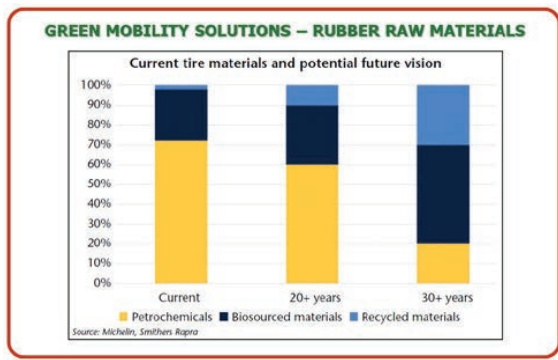
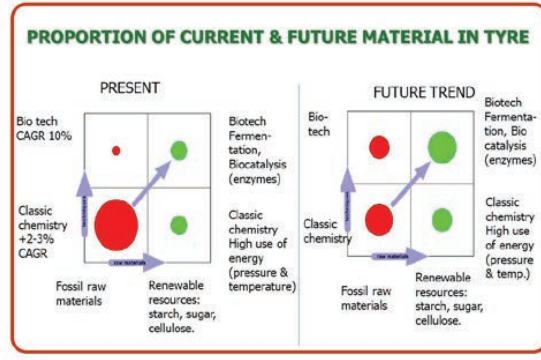
Sustainability - Tyre Industry



Sustainability – Rubber Material Development Trend



- S-SBR modified with different coupling agent/functionalised.
- Rubbers containing functional groups over the entire length of the backbone.
- Tailor made polymer
- Magneto-rheological elastomers
- Nano Structure Carbon black, Functionalised Carbon Black, Latex Carbon Black Master Batch, Carbon Black from Bio-mass
- Corn Powder/starch as filler material
- Highly dispersible silica with environment friendly silane coupling agent.
- Based on the principle of bionics natural materials are under investigation. To name a few are Natural Silica, Nano clay, Nano Calcium Carbonate, Montmorillonite Clays, Carbon Nano Fibers, Polyhedral Oligomeric Silsesquioxanes, Carbon Nano Tubes & Graphene.
- Adaptive Material - Tyre properties may adjust to service conditions using “smart” materials
- Fibres/cords :Aramids, Cellulosics, Hybrid cords, Steel
- Process oils: Natural sources (soya, corn, sunflower, palm, neem, castor oil, orange peel)
- Inner Liners - Less permeable polymers/composites, Lighter weight & Elimination
- Stabilisers – REACH Compliance
- Cure systems - reversion resistance, elimination of zinc



Intelligent / Smart Materials for Auto & Rubber Industry - EV

- Self healing materials
- Coatings
- Memory Materials
- New E conductive materials
- Materials for energy storage
- Electro responsive materials
- Solar Materials

Sustainability – Tyre Industry (Design/ Construction/Manufacturing Trend)

Design

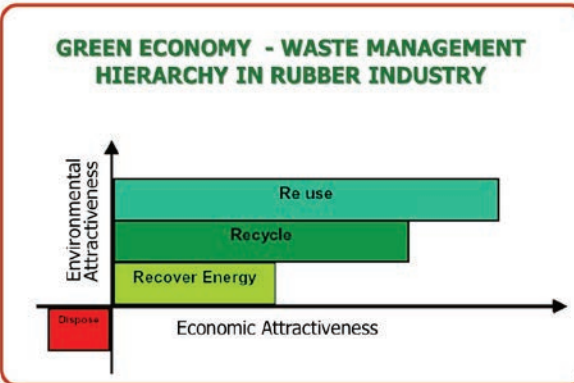
Modelling, FEA, Rapid prototyping & 3-D printing

Construction

Low weight, Solid (or non-pneumatic), Wheel/tire in one (e.g. Tweel), Taller/thinner, Integrated with wheel assembly, Smart & Intelligent, Adaptive, New tread patterns and Run flat etc.

Manufacturing Trend

Manufacturing technology is also becoming more sophisticated in their integration of complex electronic control system with precision engineering thus paving the way for vast improvement in efficiency of manufacturing process and quality of the product. Limits of variations are getting tightened & constancy of geometrical dimensions are becoming regular feature. This also will add in manufacturing (& thereby total) cost reduction which is essential for survival in today’s fiercely competitive market. Latest development



Sustainability - Design for Environment (DFE)

All Future R&D initiatives in tyre & rubber industry will be concentrated on Design for Environment (DFE).

- **New Concept Development** - Dematerialisation, Shared used of the product, Integration of functions, Functional optimisation of products & components

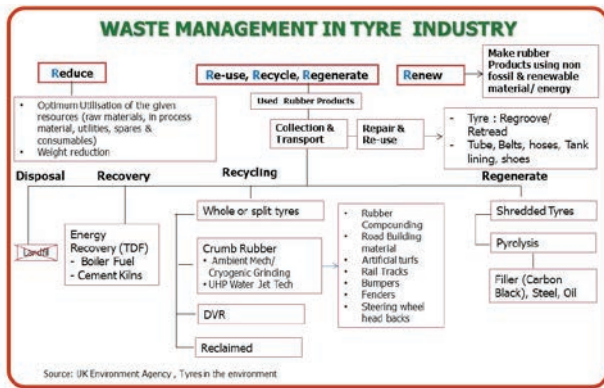
in Banbury mixers (e.g. Tandem mixing), calenders, extruders (quadriplex/pentaplex), tyre building (single stage nearly fully automatic radial tyre building machine), curing (segmented mould etc.) will improve **productivity, quality and performance** while **reducing the cost, waste and scrap**.

Besides this, the automotive & tyre industry is gradually updating their technology and manufacturing practices in line with **New trends in technologies & Manufacturing** like Advanced mixing technologies, Liquid Phase mixing, Low energy/water consumption, Renewable energy, Zero Waste, zero discharge etc. In line with Automobile industry, Tyre Industry is also looking into possibilities of implementing Smart Manufacturing **Practices** (Industry 4.0): Big Data-driven Quality Control, Robot assisted Production, Self Driving Logistics Vehicle, Production Line Simulation, Smart Supply Network, Predictive Maintenance, Machine as a Service, Self Organizing Production, Additive Manufacturing of Complex Parts, Augmented work, Maintenance & Service, etc.

Sustainability - Circular Economy – Waste Management Hierarchy in Tyre Industry

The core principles of the green circular economy are applied by tyre industry through “5R” Strategy i.e. **Reduce, Reuse, Recycle, Regenerate & Renew**.

Over and above our world is increasingly conscious of the need for a recycling society, extending the useful life of limited resources, as far as possible. Disposal of scrap tyres is ascending in the priority list of issues owing to increased awareness for environmental issues and wide publicity.



- **Selection of low impact materials** - Non-hazardous materials, Non-exhaustable materials, Low energy content materials, Recycled materials, Recyclable materials
- **Reduction of material** - Reduction in weight, Reduction in volume

- **Optimization of production techniques** - Fewer production processes, Low/clean energy consumption, Low generation of waste, Few/clean production consumables
- **Efficient distribution system** - Less/clean packaging, Efficient transport mode, Efficient logistics
- **Reduction of the environmental impact in the user stage** - Low energy consumption, Clean energy source, Few consumables needed during use, Clean consumables during use, No energy/auxiliary material use
- **Optimization of initial life time** - Reliability and durability, Easy maintenance and repair, Modular product structure, Classic design, User taking care of product
- **Optimization of end-of-life system** - Reuse of product, Re-mfg./refurbishing, Recycling of materials, Clean incineration

Sustainability – Incorporating Climate action in Business Plan

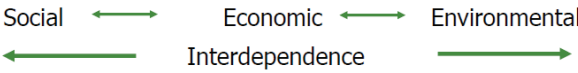
- Participate in Climate change mitigation
 - Carbon footprint (organisation, project or product) to identify hotspots
 - Set achievable reduction targets
 - Stagger mitigation initiatives
 - Consider viability of generating or taking up certified emission reduction (CER) units
- Prepare for Impacts of Climate change
 - Risk Assessment
 - Vulnerability assessment
 - Threshold analysis
 - Adaptation planning
 - Timely implementation
- Communicate to differentiate
 - Sustainability Reporting
 - Organisational or product carbon footprint label
 - Mass Media esp. Digital marketing through the social network

Conclusion

- As vehicles are one of the main source of air pollution responsible for poor urban air quality, suitable measures should be taken by all

concerned to build a green sustainable future through Green Economy.

- The challenge today is to sustain and further improve the air quality gains even as the city is growing and motorising rapidly. This is possible if strategic use of natural gas, electric power and renewable energy can increase along with aggressive clean up of all main stream fuels and technologies to cut toxic emissions (GHG) at source.
- Challenge to Zero-nize on environmental impact, fuel consumption, input cost & energy and the effort to Maxi-mize on safety, reliability, durability, handling, comfort and operational efficiency to continue.
- A change of thinking and a change of culture is needed for pursuing green economy in rubber industry



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Creativity is a ladder for Psychological Safety

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Abstract

The secret of creating a happier work place is, employee engagement. This is one of the key factors which leads the organization towards the success. Thereby, the psychological safety of the employees is one of the key element of building an engaged work force. By providing opportunities to promote workplace creativity, the organizations able to create engaged work force. Therefore, this article confirms that through creative work place, the organizations can build engaged work forces, which will carry the organizations towards the success.

Introduction

Obviously, the work force is the most important resource of any organization. Thus, every activity that they do, follows the targets of the organization. Unfortunately, over half of the employees are being stressed due to the stressors of the work place. Such as; lack of support, unreasonable time pressure, improper communication, high work load, lack of recognition and the working environment including the infrastructure, noise levels, dust, temperature and ventilation, so on. These stressors directly affect the productivity of the employees. As a result, most of the employees shows the symptoms of burn out, dis-engagement, low morale and even resignation.

Hence, invest on the creative work place will definitely manure the process of developing an engaged work force.

In order to be a successful and sustainable organizations, the organizations have to identify the potentials of creativity, not only for seeking it out, but also to invest on it.

Work Place Creativity

When thinking about creativity in the work place, one may interprets that it is mere promotional stuff or some kind of advertisements. But, creativity is beyond just creative outputs. According to Bilton, creativity is a combination of novelty and usefulness. According to

Maslow, creativity is part of the process that can be used in problem solving (Bilton, 2007).

However, defining the word creativity in organizational perspective, the definition can be vary according to the cultures of the organizations and the objectives of the organizations.

According to Robinson and Stern (1998), it is impossible to predict what creative acts will be, who will be involved in that and how and when it will happen. In fact, creativity often results of unexpectedly discovering something by chance, either that will solve a problem of the organization or, create new opportunity for the growth the organizations. Also, it is a professional setting which encourage the innovative ideas and practices within the organizations. Further, the employees have the freedom to introduce new ways to approach their tasks and assignments in much more productive manner.

Individual roles towards creative work place

➤ Employee role

Obviously, each and every employee in the organization should be given chances to contribute to the creative work place. According to Williams & Yang (1999), it is important in an organizational culture that employees have opportunities and freedom to be creative, as this is a part of what keep the organization competitive.

In addition, when interacting the employees with different educational levels, experiences, skills, etc, definitely there will be creative ideas. Hence, it is a responsibility of the organization to encourage the employees and create flat forms on this regard.

➤ Management role

The management team members have to be good listeners. Seppala (2016) says that, when we are in a room there are no titles, grades, seniority. All voices have equal weight and all have equal time. Everyone is in relationship that is based on honesty and trust.

To achieve engagement towards creative work place, the employees need to feel that they are recognized by the

management and their opinions are accepted and they are value to the organization. Therefore, it is a duty of the management to convey that every employee is value to the organization and always there is a place to their voice.

Work place happiness with creativity

The organization can use creativity as a tool to make employees happy. That will impact on the employee engagement as well. However, the creativity can be subjective so too can happiness. It is true that Happiness cannot be forced. It requires healthy culture of the organization as well as maturity of the employees.

Job satisfaction and employee engagement

The world happiness report (De Neve & Ward, 2017) reveals that the employee engagement goes hand in hand with the employee’s level of satisfaction with job. The engaged employees are not doing their jobs just for the sake of doing, instead, they try their level best to give their fullest output for the growth of the organization. Earning lot of money never provide job satisfaction. Instead, the employees those who are capable of planning their day today work have high level of happiness and job satisfaction.

Creativity towards Psychological Safety

Harvard Professor, Amy Edmonson (1999), defines that the psychological safety as an environment where employees do not fear to be themselves. Also, it is a shared belief of the team that they are free to take risks, express their ideas freely, ask questions and accept the mistakes. All without fear of negative repercussions.

According to Maslow’s hierarchy of needs, a person’s unmet needs serve as motivator for their behavior (Evans and Ward, 2007). However, lack of feeling safe in an organization may result, feeling of not belonging to the organization. On the other hand, when the culture of the organization does not supporting the employees’ feeling of belonging, that can lead to destroy the trust between the employees and the operation team (Management).

In addition, the climate of the organization also has impact on employees’ feeling of belonging. As per Akvall, climate is the experience of everyone in the organization. He identified 10 dimensions that build this climate.

Table 01

Dimension	Definition	High	Low
Challenge	Emotional involvement in the task	People are happy and they are willing to invest more energy	People are not happy
Freedom	Independence in behaviour	Problems are discussed freely and people think that they are the power to take initiatives	People are passive and they think that they cannot break the rule
Idea support	The way that new ideas are treated	Superiors and peers pay attention for what is suggested. They creat ways to test and trial new ideas	Suggestions are considered as wrong ones
Trust and oppeness	Emosional safety in the relationships	Every offer new ideas without fear	People are suspicious of each other
Dynamism & Liveliness	The amount in which the environment is eventful	New things happening and new ideas flow constantly	No new projects
Playfulness & Humor	sponteneity	Work environment is so relax and people crack jocks so on.	The atmospHERE is gloomy. Laughing and jocking considered inappropriate
Debate	Crashes of ideas	People are interested of discussing new ideas	No discussion on new ideas
Risk taking	Tolerance of uncertainty	People oftenly participate in new opportunities	People are hesitate to act on new opportunities
Idea time	The amount of time invest on new ideas	People go extra mile for new ideas	People are limited only to thier given tasks
Conflicts	Personal and imotional tension	Gossip and slander exist	People are mature in their interaction

As per the above table, the first nine dimensions are positive and high rank is expected. While the tenth dimension is negative and the organizations need to work on this area. Mere implementing the climate dimensions is not adequate, as employees are not live in a bubble. Each employee has his own values and that will have an impact on his professional self. Kotter (1996), says that most of the development takes place in the workplace as people spent most of the time in the workplace.

As per Sahlin (2013), creative environment embodies generosity, community, qualifications, diversity, trust, equality, curiosity, freedom spirit and small-scale size. According to him the creative work environment is so warm and welcoming. Creative work environment create warmth both in physically and mentally. Hence, the employees who work in such creative environment have sense of belonging towards the organization too. Hence, this depiction of creative work environment echoes the characteristics of Amy Admondson’s Psychological safety.

➤ Reduction of stress

As per the study conducted by the American psychological association, there are 77% of employees reported feeling stressed. Among them 73% reported experiencing psychological symptoms caused by stress. This stress can cause ripple effect when interacting with family and friends.

Csikszentmimihalyi (1990) cautions that our energy is weaken when we are regularly threaten by the things that are not aligning to our goals and that are deviating us from our goals. As per Runo (2014), creativity helps the individual to maintain both psychological and physical health & Safety. Therefore, the concept of creative work place definitely treat such stress of the employees, so that they may be happy in their work place and they will be happy in their family lives as well.

➤ Failures are the pillars of success

In fact, the skills and talents are not developed over night. Fullan says, people with a fixed mind set see their mistakes as negative, and

therefore, mistakes are something to be avoided. Such people never take risks and strive towards innovation as they are afraid of failures. The employees are frighten. The organizations that have such culture will not be sustained.

Heifetz, Grashow and Linsky (2008), describe that this is as “permission to fail”. They say that the organizations need to broaden their definition for success so as to adopt an experimental mindset, also need to change the vocabulary to be one of an open mindset where failures are acceptable and try for small experiments as they can be easily bounce back. On the other hand, in a creative work place always failures are accepted.

Hence, it is the responsibility of the Leaders to provide necessary knowledge and encourage the employees for new innovations by providing the required resources. In a failure, the Leaders are expected to encourage the employees to pick themselves back up and to go out there to try again. Organizations can achieve growth by promoting culture where failures are accepted and such failures will open new horizons for the organizations.

Conclusion

Tanner and Reisman (2014), said that the employees respond for optimism in different ways. Some going after social connection, some expect the appreciation of the managers, some need help to setting up their goals and achieving their goals. In fact, happy employees are vibrant in achieving their goals. Also, they are inspired to innovate new things. In an organization, creativity and engagement along with the psychological safety, inspire the employees towards the success.

According to Maslow (1971), people become anxious when their needs are not met. These needs would be

related to safety, belonging or accomplishment. These negative impressions affect to shape up the work place behavior of the employees.

Moreover, by enabling the opportunities for enhancing the psychological safety of the employees through creative work place and engagement, will definitely thrive the organization towards the success.

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New Developments in Recycling of ELT (end of life tires)

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The true wealth is created by value addition and not by trade and commerce. The value addition can only be done by doing something beyond tradition. The Reclaim industry has not changed in last 100 years. The tyre manufacturers which consume 75 % of rubber hardly use it, due to very poor physical properties.

The story of the End of Life tyres - the environmental hazard.

John Boyd Dunlop, a Scottish veterinarianian was inventor of the first practical pneumatic tire in 1888, he invented it for his son’s tricycle.

It took another seven years for someone to take the leap. André Michelin and his brother Edouard, who had previously patented a removable bike tire, were the first to use pneumatic tires on an automobile. Unfortunately, these did not prove durable. It wasn't until Philip Strauss invented the combination tire and air-filled inner tube in 1911, that pneumatic tires could be used on automobiles with success.

As the use of trucks and other vehicles increased a new problem arose. There was hardly any use of the waste tyres. A few tyres were used as boat fenders, as fuel, and making distillate oil by pyrolysis.

During Second World War the Japanese controlled the Rubber producing countries in the east and no Natural Rubber was available to western countries, President Roosevelt ordered setting up of forty synthetic rubber plants overnight in USA and England. The Reclaim rubber plants also expanded all over Europe and USA. Even tyre companies put up their own Reclaim plants. In India both Dunlop and Firestone had in-house Reclaim rubber plants.

As USA and Europe produced sufficient quantities of Synthetic rubber, the Reclaim rubber industry died its own death, primarily due to poor physical properties and high pollution.

Chinese industrial revolution started but it neither had

synthetic rubber nor NR. Qingdao University created a special cell to do research to improve quality of reclaim rubber. Today China produces 60, 00,000 Tons, more than 90 % of total world production. India produces 2, 50,000 Tons per anum and Netherland and Africa also manufacture about 50,000 Tons per anum.

In the meanwhile huge stockpiles of ELT tyres are being created all over the world particularly in the developed countries, causing monumental environmental issues. Fires erupted in stockpiles cannot be doused till entire stock is gutted causing poisonous air pollution miles around.

The recycling of these tyres without causing pollution became a major challenge.

In 2004, after ten years of research involving Michelin, Continental North America and Ford motor co, a report was published by Waste management Board California, saying that the best solution to recycle ELT tires, was to make Micro-fine rubber crumb of 80 & above mesh, by ambient grinding, without causing any pollution. The micro-fine rubber powder (MRP) when added to new tire did not compromise on properties. The recommended percentage was 5% on weight of the tyre. (Equal to 10 phr)

MICHELIN

October 18th, 2017, Michelin announced, quote” it had acquired Lehigh Technologies a speciality materials co, that uses patented cryogenic turbo mill technology to transform rubber from end-of- the-life tires and industrial goods into materials for new tires and industrial goods into materials for new tires and other products, reducing the amount of raw material initially needed.” “The firm produces highly engineered, versatile raw materials called micronized rubber powder (MRP).” “Its customers include some of the largest tire companies in the world".

It was further reported that more than 500 million tyres were produced with complete success.

AMBIENT (MECHANICAL) GRINDING

The Cryo grinding had limitation of use. Because of its less fractured surface due to freezing of waste tyre, to below glass transition temperature, the microfine particles had less crevasses. Therefore strong physical bond with the rest of compound could not be achieved beyond 10 phr of MRP addition.

Tinna Rubber and Infrastructure Ltd New Delhi India developed mechanical grinding process operating at ambient temperature. It successfully developed very high structure and very high surface area as compared

to Cryo-grind material. The ambient grind material has twice the surface area of that of Cryo grind material therefore 140 mesh crumb can be used up to 30 phr without loss of properties.

It proved to be a very successful NEW INNOVATION and a profitable end use of waste tyres was found. There was no loss of properties even up to the addition of 20 PHR on successful dispersion of the same in a new compound.

A study was done to compare Cryo-grind and ambient grinding. The results are tabled below.

Comparison Report for Cryogenic and Ambient Grinding Crumb						
			Ambient		Cryo	
S. No.	Compound	PHR	Test Description	Unit	0-PHR	10-PHR
1	NR	70.00	Curing Time	Min	12	12
2	PBR	30.00	Hardness	Shore A	66	62
3	ZnO	5.00	Tensile Strength	(kg/cm ²)	194.84	188.68
4	Stearic Acid	2.20	Elongation at Break	%	428.75	457.36
5	TDQ	1.50	Modulus at 100%	(kg/cm ²)	20.87	26.36
6	TMT	0.10	Modulus at 200%	(kg/cm ²)	71.28	64.84
7	Crumb Rubber	0.00	Modulus at 300%	(kg/cm ²)	129.61	114.29
8	Carbon HAF	57.00	Specific Gravity	-----	1.14	1.14
9	Oil 710	8.00	Curing Temperature	(⁰ C)	150	150
10	Sulphur	2.20	Curing Time	Min	14	14
11	CBS	1.00	Abrasion Resistance Vol. Loss	mm ³	69	74
12	Rosin	2.00	Temperature	(⁰ C)	150	150
13	Total	179.00	Arc	Degree	3	3
			Chart Speed	Min	30	30
			Torque Range	lbs	250	250
			Scorch Time ts ₂	Min	4.22	3.65
			Cure Time T _{c90}	Min	7.37	6.68
			ML	Lbs	14.89	13.33
			MH	Lbs	122.04	110.6
			Compound Cost	Per KG	127.03	122.06

Cryo crumb shows high modulus, and higher hardness, Ambient crumb has higher TS, Better abrasion.

IRMRA EVALUATION

80 mesh crumb was evaluated at IRMRA laboratory using a standers tread compound as below.

NR-75 Phr, PBR-25 Phr, ZnO-3 Phr, St. acid-2 Phr, TDQ-1 Phr, MC wax-1 Phr, Crumb 80

mesh-0, 5, 10 Phr, Carbon330-55 Phr, Oil 710-8 Phr, Sulfur-2.25 Phr, CBS-1 Phr,

Note Carbon had to be reduced by 5 phr to maintain hardness when using 10m phr of 80 mesh crumb.

Test results are given below.


IRMRA
 Helping Rubber World in Building Better Future

IRMRA REPORT

S No.	Test Parameters	Unit	80 Mesh		
			0 phr	5 Phr	10 Phr
1	Before Ageing				
	a. Tensile Strength	Kg/cm2	261	245	260
	b. Elongation @ Break	%	580	610	590
2	c. Modulus @ 300%	kg/cm2	103	98	96
	After Ageing @ 700C for 72hrs				
	a. Tensile Strength	Kg/cm2	258	242	248
3	b. Elongation @ Break	%	510	510	515
	c. Modulus @ 300%	kg/cm2	131	128	126
4	Hardness	Shore A	60	63	64
5	Compression Set @ 700C for 24 hrs 25% compression	%	5.6	9	13
6	Ozone Resistance Test @ 50 pphm for 72 hrs	Visual	No Crack	Crack Observed	
7	Specific Gravity	g/cc	1.10	1.11	1.11
8	Abrasion Resistance Index	ARI	107	109	108
9	Mooney Viscosity ML (1+4) @ 1000C	MU	39	54	53
10	Dynamic Mechanical Analysis (DMA) 5Hz @ RT	Tan Delta Storage Modulus	0.068	0.061	0.072
		Storage Modulus	2.58x106	2.58x106	2.58x106
		Thermo gravimetric Analysis (TGA)			
	Low Boiling Material	TGA	7.68	7.17	6.88
	Polymer Content		61.33	61.88	61.76
	Carbon Black Content		29	28.08	28.55
	Ash Content		2	2.8	2.7

• While adding 10 PHR crumb, carbon N 330 was reduced by 5 PHR.

REVOLUTIONARY INNOVATION

Manufacture of Microfine Rubber Powder (MRP), has all the advantages

- IT CAN BE ADDED AS A RAW MATERIAL IN NEW TYRE COMPOUNDS WITHOUT LOSS OF PROPERTIES.
- IT IS PART OF CIRCULAR ECONOMY
- IT USES WASTE TYRES WHICH OTHERWISE ARE AN ENVIRONMENT HAZZARD.
- IT REDUCES THE USE OF PETROLIUM BASED MATERIALS LIKE CARBON, OILS AND SYNTHETIC RUBBER.

- HELPS IN REDUCING GLOBAL WARMING BY REDUCING CO2 EMISSIONS
- IT IS LOW COST AND NOT SUBJECTED TO VAGERIES OF MARKET FLUCTUATION DUE TO PETROLIUM PRICES.
- IT DOES NOT CAUSE ANY POLLUTION.

Tinna Rubber and infrastructure Ltd a New Delhi base company IS THE LARGEST PRODUCER of MRP by ambient process which gives fractured particles with highest surface area.

ROADS

Tyre crumb is now widely used in rubberising bitumen used in the road surfacing. By adding 10 to 20 parts of tyre crumb in Bitumen, for the road surfacing enhances the life of roads to 10 years.

- Roads do not break during rains, since rubber makes it waterproof
- The bitumen being rubberised does not belt in extreme atmospheric conditions.
- Nor does it develop cracks in extreme cold at minus temperatures.
- Very cost effective the cost of tyre crumb is 60% of that of the Bitumen.

ALL OVER THE WORLD ROADS ARE BEING MADE BY USING RUBBER CRUMB ADDED 10 TO 10 PARTS IN THE BITUMEN.

Other possibilities

- Work is going on developing high T.S. reclaim with stable Mooney.
- Activated crumb rubber , in which case the tyre crumb is surface treated with certain chemicals so that it gets combined to the new compound, and no reclamation is required.
- Pyrolysis is the oldest method of using waste tyres, where rubber is dry distilled and high caloric value fuel oil is produced. It is widely in use all over the world. However sale is dependent upon the vagaries of petroleum prices. Being a simple technology it can be very competitive.



UNLOCKING WORLD CLASS BONDING AGENTS FOR HIGH PERFORMANCE RUBBER & PU TO SUBSTRATE BONDING SPECIAL FOCUS ON ONE COAT BONDING TECHNOLOGIES

The Cilbond™ range of Rubber and Polyurethane to Substrate Bonding Agents allow engineers to combine the different properties of rubber, urethane, plastic, metal, and fabric to develop industrial components with benefits that outweigh the sum of their parts.

This combination of benefits include flexibility, strength, abrasion resistance, chemical resistance, cost, and weight - all features critical to the Automotive, Aerospace, Petrochem, and Transportation industries that H.B. Fuller serves.

Developed at our in-house research and development laboratory, the Cilbond™ range of products is at the forefront of technology with respect to performance, versatility, and the environment.

The Cilbond™ bonding agents are relied upon in the toughest environments across industries as diverse from Aerospace & Automotive to Marine & Defence.

CILBOND™ NEW GENERATION ONE-COAT TECHNOLOGIES:

Convention states that polymer to substrate bonding agents should always consist of a primer and a topcoat.

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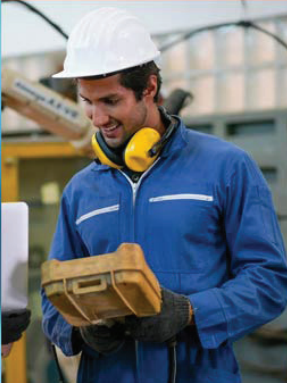
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- Pump Linings
- Suspension Bushes
- Pipe Coating and Linings
- Printing Rollers
- Seals



Natural Rubber (NR) Industry Update -2022

Manoj Udugampola

Chief Operating Officer – Rubber

1. Rubber Production

The annual requirement of Natural Rubber for internal consumption in Sri Lanka is around 150,000 MT per year. With the current production level, not even 50% of the requirement is produced within the country. Therefore, approximately 100,000 MTs of Rubber is imported every year.

The NR production in the year 2022 was only 70,870 MT. which shows a decline of 7.81 % from the previous year’s production of 76,886 MT. With 20,000 MTs are exported in the form Latex Crepe, Ribbed Smoked Sheets and Centrifuged Latex only around 50,000 MTs of natural rubber is available for the rubber product manufacturing sector in Sri Lanka.

The natural rubber production in the country has been severely affected since 2010 due to various reasons. The main reasons for low production at present are;

- Low productivity
- Shortage of skill harvesters
- Presence of circular leaf spot disease
- Fluctuation of rubber prices
- Lack of replanting old rubber lands
- Lack of lands for expansion
- Recent ban in Fertilizer and Agro-chemicals

Being a pioneer in the NR industry in Asia, Sri Lanka was at an advantageous position in the market for NR vis-à-vis its global competitors. However, an analysis of the current status demonstrates weaknesses in performance compared with many new comers to the NR industry especially in the areas of production, productivity and technological innovations. Position of traditional Sri Lankan NR —brandsl has eroded over the years due to lack of initiatives and innovations. These factors have led to lower profitability at times of cyclical price decline, which is an inevitable condition in commodity markets linked to stochastic systems. This has affected the decisions of producers in relation to replanting, new planting and even production.

The NR production during last 05 years is given below

Year	Production (MT)
2022	70,870
2021	76,880
2020	78,200
2019	74,700
2018	82,600

2. Rubber Productivity – Yield per Hectare (YPH)

The Yield per Hectare recorded in the year 2022 was 649 and reflects a decrease of 4% over the previous year 2022.

The productivity of Sri Lanka rubber sector has been one of the lowest in the world. The average YPH of Sri Lanka has been recorded around 679 kg. at present which is far below the other countries. Whilst our neighboring country is recording a yield of over 1450 kgs per hectare, Vietnam and Thailand yields over 1600 kgs per hectare. The chart below gives the YPH of last 5 year in Sri Lankan rubber industry which shows

Year	YPH (kgs)
2022	649
2021	679
2020	649
2019	658
2018	774

Once again, Skill tapper shortage, lack of replanting old rubber, poor stand per hectare and Leaf diseases are the most common factors concerning for low productivity according to industry sources.

3. Rubber Extent

According to the statistics available, the total extent under rubber cultivation in Sri Lanka is around 138,300 Ha. which includes approximately 16,000 hectares under immature phase. The total rubber extent in the country has not seen a significant growth during the last decade.

Year	Mature Extent	Immature Extent	Total Extent (Hectares)
2022	123,412	16,322	139,734
2021	123,295	16,587	139,882
2020	121,398	17,203	138,601
2019	114,112	24,103	138,215
2018	107,321	30,108	137,429

It is observed that the immature extent is gradually decreasing. New Planting and Replanting need substantial investments and need to be encouraged with a subsidy scheme as first 6 years after planting (immature phase) does not generate any income to the grower.

Under the Rubber Master Plan which could be considered the Road Map for Rubber Industry developed for 2017 -2026 period, expanding the rubber cultivation in non-traditional areas has been identified as a major initiative.

4. Natural Rubber Prices

Despite the declining trend prevailing in most countries since 2011, an increase is observed since 2019. The Natural Rubber prices reached it’s peak at the Colombo Rubber Auctions in the month of July 2022 fetching Rs.1,450/- per kg. for Latex Crepe No.1X. Since then, the prices of this commodity dropped to Rs.628.33 per kg. by December 2022.

However, year 2022 remains as the year with the highest price for Natural Rubber in the history. Similarly, the most produced grade in the country – RSS rubber reached it’s peak of Rs.800/- in June 2022 at the Colombo Rubber Auctions. The price of RSS No.1 declined to Rs.517/67 per kg. in the month of December 2022. The annual average of Latex Crepe No.1X was Rs.845.70 per kg. whilst RSS No.1 average was Rs.647/- per kg. The highest ever price of Ra. 1450.00 was recorded in the month of July 2022.

The movement of rubber prices in Colombo Rubber Auction during last 5 years are as follows;

Year	Latex Crepe No 1X	RSS 1 No 1	Scrap Crepe No 3X Brown
2022	845.70	647.47	479.45
2021	635.16	458.52	404.11
2020	360.74	348.27	240.33
2019	302.04	289.92	236.21
2018	321.79	281.64	208.34

5. Rubber Market

Sri Lanka maintains its position as a producer of cleanest Natural Rubber termed as Latex Crepe (LCR) which is also known as Thick Pale Crepe (TPC) and is the largest exporter of crepe rubber to the international market fetching a premium price over all other types and grades.

However, the NR prices have started decreasing since August 2022. The Latex Crepe No 1X which was traded at Rs. 1450.00 per kg has reduced to Rs. 500.00 level at present.

It has been also observed that the rubber smallholder sector which manages around 70 % of the cultivated extent, do not undertake harvesting operations when the rubber prices are uneconomical.

6. Rubber Product Manufacturing Sector

The Rubber Product Manufacturing Sector needs approximately 150,000 MT of natural rubber per annum. Considering the importance of the sector to the country’s economy, the government of Sri Lanka has allowed the them to import their requirement of NR to the country.

At present, Sri Lanka is the largest exporter of industrial solid tires used in the agricultural, industrial and logistics sector vehicles including forklift trucks, airport vehicles, heavy-duty transport vehicles, platform trucks, and other industrial vehicles. A few companies also manufacture pneumatic tires which is a recent development. Availability of raw materials, labour, expertise and experience have made Sri Lanka as the global hub for solid tyres.

Further, Sri Lanka is the 5th largest exporter of Latex Gloves to the world. The Natural Rubber Latex Gloves offer greater strength, sensivity and protection against a wider range of pathogens and widely used for medical, industrial and house-hold purposes around the world.

7. Import of Natural Rubber

Import of Natural Rubber is now closely monitored by the Board of Investment and Ministry of Plantation Industries so to ensure that there would not be a negative impact on the local rubber prices. The process however, does not hamper the production flow of rubber product manufacturers, considering their contribution to the national economy.

The Ministry of Plantations Industries, Ministry of

Industries, Board of Investments (BOI), Sri Lanka Customs are coordinating this exercise for smooth operations of the activity.

8. Future and Outlook

Global markets opportunities are in the rise for natural rubber and country can secure a much larger share in the global market. As the global demand for rubber-based products are expected to increase with the improvement of life quality and per capita income in the South American and African countries. The country an aggregate annual turnover of nearly 4 billion USD by 2026 with sufficient infrastructure, policy support, and other facilities.

The global economy weathered the storm of the pandemic and continued to grow during the year 2022 to an impressive 5.67 percent over the previous year. Globally people are traveling a lot more than they did a year ago which are positive signs for the rubber industry. Whilst some of the smaller nations have been resilient some others have been badly affected to the point of hunger, starvation and anarchy.

Unfortunately, Sri Lanka, which has been fairly resistant to the global economic fluctuations in the past took a massive toll during this time. Our GDP is expected to contract 9.2 percent in 2022 and a further 4.2 in 2023. Sri Lanka has seen its worst economic crisis since independence in 1948 due to poor governance. For the first time, we defaulted on our sovereign debt and brought about economic instability and hardship on its people never witnessed before.

Despite the global economy being hit badly by the pandemic in 2020 and 2021, the natural rubber industry posted a strong recovery in demand with an impressive 8.7% growth in 2021 and 2022. Amidst the pandemic the rubber production decreased in 2022 by 7.8% to 70870 MT over the previous year. However, NR prices also improved and averaged around US \$ 1.68 per kg for TSR grades and 2.17 per kg for RSS grades last year despite the various challenges The global supply chain disruptions were observed due to shortage of chipsets and high shipping costs. However, rubber prices declined 39.10 U.S. cents /kg or 21.93% since the beginning of 2022. The Colombo Rubber auctions recorded highest ever price for Latex Crepe 1X of Rs. 1450.00 per kg in the month of July 2022 taking advantage of the rupee devaluation.

In additional to stormy global economic issues, Sri Lanka too has had to face its own share of home brewed economic woes as a result of poor governance and economic policy. Commencing with the ban on chemical fertilizer and agro-chemicals the rubber industry has had its share of supply shortfalls.

Furthermore, the lack of Agro chemicals, especially fungicides have escalated the Circular Leaf Spot Disease (CLSD) spread in the fields. The erratic weather pattern during the year increased the disease in all rubber growing areas in Sri Lanka.

In the latter part of the year, the NR prices showed a declining trend and in the trend continues in the year 2023, the effect of the declining prices will be more on the rubber plantations / estates in Sri Lanka. With low farm gate price for raw rubber and escalating cost of production particularly with high worker wages, farmers are reluctant to replant their aged and unproductive rubber lands. There is a tendency to utilize rubber lands for other economic ventures in traditional growing areas and also a slow progress in expanding rubber cultivation in non-traditional areas. Therefore, a need has arisen to focus on planting rubber in non traditional areas where land is available and the climatic conditions too are more favourable. The development activities should target to increase not only the productivity of rubber but also the overall land productivity and the growers’ income.

Avenues for reducing the cost of production and efficient use of workers should be at a high level of consideration. Further, whilst supporting to expand rubber cultivation to new areas, projects should be launched to remunerate the environmental benefits of rubber cultivation for the benefit of both rubber growers and product manufacturers.

The immediate requirement of the NR industry is to increase the production and productivity. Then the much-needed foreign exchange could be expected by way of exporting the extra production that would be available. Similarly, the additional production could be channeled to the rubber product manufactures in the tyre and latex industry which too would save foreign exchange that is used to import Natural Rubber from international markets.

The Effect of Chemical Priming of Rubber Nursery Plants on Growth and Abiotic Stress Alleviation under Drought Conditions in the Intermediate Zone of Sri Lanka

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Introduction

In the wake of climate change, abiotic stress in plants has now been recognized as one of the biggest threats to agricultural productivity all over the world. Drought and heat stresses are the two abiotic stresses undoubtedly having a huge impact on the growth and productivity of crops. These stresses in isolation and/or combination induce numerous adverse effects in plants impairing morphological and physiological changes of plants and eventually causing severe reductions in plant growth, development and overall productivity (Khan and Khan, 2013).

With the scope of further expansion of rubber to Non-traditional areas such as Moneragala, Padiyathalawa, Ampara, Vavuniya, Hambanthota, and Puttalam in the Intermediate and Dry Zones of the country, many research was carried out in alleviation abiotic stress such as drought and heat. Nevertheless, drought-tolerant rubber clones are yet to be identified in Sri Lanka, and therefore, it is essential to prime (preconditioning) the rubber nursery plants for enhanced tolerance to abiotic stresses such as drought and heat. Chemical priming is a promising area in plant stress physiology and crop stress management which involves exposure to a priming agent such as a natural or synthetic chemical compound. Sodium nitroprusside (SNP) and Salicylic acid (SA) are two widely used such chemical primers and plant growth regulators that have shown a significant effect

on plant abiotic stress tolerance. Therefore, this is paper shares the results obtained by the concurrent research conducted for the exogenous application of Sodium nitroprusside (SNP) and Salicylic acid (SA) to rubber nursery plants in order to mitigate the drought stress when introducing them to Non-traditional areas in the Intermediate Zone of Sri Lanka where the prolonged dry periods are prevailing in every year.

Use of Sodium Nitroprusside (SNP) for enhancing root architecture and growth of plants

Nitric oxide (NO) donor SNP is an important endogenous signaling molecule involved in a variety of plant functions such as plant growth and development, and responses. Exogenous NO mitigated the decrease in plant growth caused by drought and heat through increasing antioxidant enzymes and thereby alleviating oxidative damage, accelerating proline accumulation, enhancing photosynthesis (Sanz *et al.*, 2015). Therefore, the effect of Sodium nitroprusside (SNP) as a NO donor on the growth of rubber nursery plants was investigated through many nursery experiments conducted over several years. Nayanakantha *et al.* (2014 and 2016) reported that exogenous SNP could improve the root architecture and growth of rubber seedlings under the protected house and nursery conditions. Figure 1 shows the effect of different concentrations of NO donor SNP that increases the root architecture of rubber seedlings after 14 days of transplanting in a young budding polybag

nursery. Plant treatment with different concentrations of SNP in a range of 50 μ M - 300 μ M as soil drench was found to be the best range that significantly responded to the growth of rubber seedlings in a prolonged drought period (Nayanakantha *et al.*, 2014).

Use of Salicylic acid (SA) to alleviate drought stress in plants

Similarly, Salicylic acid (SA) is an important priming agent known to alleviate drought stress in rubber nursery plants. Several research studies were carried out during 2016-2017 to investigate the effect of the exogenous application of Salicylic acid on the growth performance of rubber nursery plants under drought stress conditions in the Intermediate Zone of Sri Lanka (Nakandala, 2018). Pre-conditioning of rubber nursery plants by using an exogenous application of SA has been identified as a feasible solution for enhancing the growth of rubber nursery plants under drought-stress conditions. Nakandala (2018) reported in her postgraduate research study that the rubber seedlings treated with 100 ml of SA at a concentration in a range of 0.3 to 0.5 mM as a soil drench in monthly applications can significantly impact on stress tolerance of rubber nursery plants, thereby reducing the total irrigation requirement of the rubber nursery plants by 25 % when introducing them to drought-prone areas in the Intermediate zone of Sri Lanka. Based on the overall results obtained from the above research studies revealed that drought stress could be alleviated by applying Salicylic acid and Nitric oxide donor Sodium nitroprusside significantly

and have identified to use of reducing the total irrigation requirement of rubber nursery management when introducing them to drought-prone areas in the Intermediate zone of Sri Lanka.

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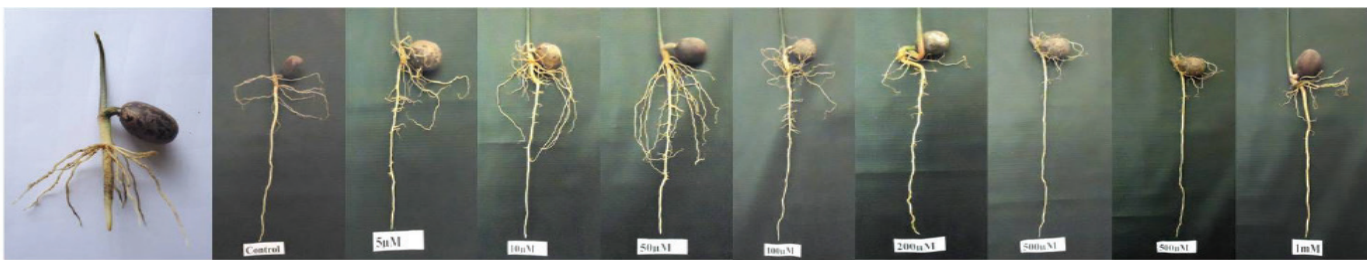


Figure 1. Effect of NO on root architecture of rubber seedling treated with different concentrations of NO donor SNP and the observations were made 14 days after NO treatment. a: germinated rubber seedlings at the time of transplanting. b: control soil drench with water, c: 5 μ M SNP, d: 10 μ M SNP, e: 50 μ M SNP, f: 100 μ M SNP, g: 200 μ M SNP, h: 300 μ M SNP, i: 500 μ M SNP, j: 1000 μ M SNP

A Sailing Company, Qingdao Xiangjie Rubber Machinery Co.Ltd.

Qingdao Xiangjie Rubber Machinery Co., Ltd. set up in 2003, a professional company in production and sales of rubber equipments, is located in the West Coast of Qingdao, China. Its advantageous geographical location provides convenient conditions for customer visiting and products transportation by sea, land and air.

After 20 years of development and growth, Xiangjie has formed a variety of press machines that meet various rubber products, and also can accurately process and manufacture various non-standard products according to customer requirements. Good quality wins unanimous praise from customers.

The company has gotten ISO9001:2008 quality system certification, EU CE certification, and French BV certification, and has been awarded the National High tech Enterprise.

At present, the large and oversized press series are the main products of Xiangjie, including solid tire press, conveyor belt production lines, bridge and building shock absorption vulcanizing machine and sealing ring vulcanizer for plate heat exchanger. Xiangjie also can produce custom-tailor equipments to meet the special needs of different companies.

1. Solid tire press series.

Being the one of main products of Xiangjie, they have different series to meet the customers. Such as solid tyre press with column or frame structures, equipped with fully automatic and semi-automatic accessory equipment for users to choose.

In 2021 Xiangjie successfully developed an intelligent solid tyre press. It has the functions of fully automatic intelligent mold and solid tire removal, raw tire storage, replacing the manual operation in the original production process with intelligent manipulators and AGV Trolley. It is a next generation of intelligent products.

In 2022, 8 solid tire pressed with segmented mold were exported to Continental Tyre Company in Sri Lanka. Excellent quality wins the favor of customers. In 2023, the customer books another 10 fully automatic solid



tire press, which will be shipped to the Continental Tyre Company soon.

2. Conveyor belt vulcanizing press series

Conveyor belt vulcanizing press series are the first main product of Qingdao Xiangjie Rubber Machinery at its establishment. They have over 20 years of R&D and making experiences in this field. Now they can make different wire rope production lines and conveyor belt production lines.



The company innovates and has launched a 3200x12600/182.0MN wire rope production line with a width of 3.2 meters, a length of 12.6 meters, and a clamping pressure of 18200 tons, which has been applied to Zhejiang Sanwei Group. It achieved a breakthrough of the first set in China. This equipment can meet the production requirements of ultra wide conveyor belts and has obtained a China national invention patent, becoming a star product of Xiangjie.

In addition, their 1750x10000 new-type downward pressure conveyor belt production line was exported to Dunlop Conveyor Company of South Africa in 2021. It was awarded the Best Supplier Award by the Dunlop Company.

3. Rubber bearing vulcanizing machine series used in bridge and building

Xiangjie also produces large vulcanizing machine series for rubber damping products used in bridges and buildings. It has a column structure and automatic push-pull device with insulation system can save heating energy by 20% -30%, reducing energy consumption of the equipment. A single cylinder can be a pressure of 3000 tons on a diameter of 1500mm. The quadruple cylinders can be a pressure of 4500 tons on a 2300x2300 plate surface. It can meet the complex production process of customer with comprehensive designed systems.



4. Sealing ring press series for plate heat exchanger are used for sealing rings of plate heat exchangers

The size of the hot plate can be special designed according to customer requirements, with a maximum width of 4.2 meters and a length of 1.6 meters. The product is applied in seals of nuclear reaction, aircraft

carrier heat exchangers.

Xiangjie launches the new type of sealing ring vulcanizing machine with a double-layer structure. The middle plate can operate independently during the spacing, improving the working space and accelerating work efficiency. The fastest running speed reaches 120mm/s, and can complete the mold pressing and exhaust action within 15 seconds. The exhaust of each layer is adjustable by 1-5 mm, and the flatness error of the hot plate is within 0.1mm. Each layer is individually controlled for temperature, and the temperature difference of the hot plate can be controlled within $\pm 2^{\circ}\text{C}$. At the same time, the upper and lower machine seats are equipped with a thermal balance system to ensure the stability of the frame during long-term use of the equipment.



In 2020, Xiangjie successfully developed an up-market heat exchanger seal vulcanizing machine for the Swedish Company Gislaved Gummi, which received high praise from customers. At present, two up-market heat exchanger seal vulcanizing machine are already in operation at the factory of Gislaved.

In addition, except the four main series products, Xiangjie also produces air spring vulcanizer, air spring sealers press, jaw type press, large press for rubber products, and tread vulcanizer for retreading tyre.

Excellent R&D team:

Xiangjie is well aware that technological innovation is the core of an enterprise. For many years, Xiangjie has been focusing on product excellence quality and R&D for technological innovation, and has obtained 1 invention patent and 25 utility model patents.

The company has its own R&D team, and has long-term technical cooperation with experts and professors from Qingdao University of Science and Technology and Shandong University of Petroleum. Regular visiting and technical exchanges with the professor bring product updating.

The technical team ensures that Xiangjie can design and produce machines that meet various rubber product requirements according to the different needs of users.

Main market:

The company has its independent import and export rights, can export products to different countries and regions around the world, and has established long-term cooperation with some well-known enterprises.

Apart from Chinese market, 80% of the products are exported to overseas markets. They sell machines to the United States, Canada; South Africa, Ethiopia, Algeria, Egypt, France, Spain and Turkey, Sri Lanka, Australia, the Middle East, India, and Southeast Asia, more than 100 countries and regions around the world.

Adhering to the concept of "Quality and Customer First, Honesty and Keeping Promise", Jingjie has won

unanimous praise from domestic and foreign customers with first-class product quality and good service.

New Sailing

With the continuous expansion of the company's business in order to meet the demand of the domestic and international markets, in March 2021, Qingdao Xiangjie Rubber Machinery Manufacturing Co., Ltd. and Hong Kong GOMAPLAST Machinery Limited jointly established Sailuojiayu (Qingdao) Machinery Co., Ltd. The new factory is with total investment is USD40 million, covers 20000 square meters. The new company integrates research and development, manufacturing, sales, and after-sales service. Currently, the new factory has been completed and put into operation.

The new company, Sailuojiayu, continues the footsteps of Xiangjie Rubber Machinery, insists on the principles of quality first, integrity first, and innovation. They will continue to provide first-class equipment and good services to new and old customers. Sailuojiayu and Xiangjie Rubber Machinery will be your good partners. Welcome visiting booth No.K1 and K14 of International Rubber Expo 2023 in Sri Lanka.



QINGDAO XIANGJIE RUBBER MACHINERY CO.,LTD.
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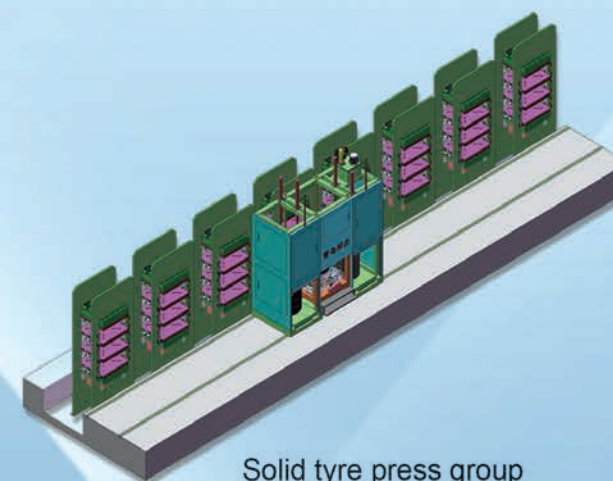
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